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Winter distribution and habitat use of lynx fisher and wolverine in Glacier National Park Montana

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WINTER DISTRIBUTION AND HABITAT USE OF LYNX, FISHER, AND WOLVERINE IN GLACIER NATIONAL PARK, MONTANA

by

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Winter detection surveys for Canada lynx (*Lynx canadensis*), fisher (*Martes pennanti*), wolverine (*Gulo gulo*), and other species were conducted in Glacier National Park (GNP), Montana from November 1998 to April 2000. Over 1500 km of transects were traveled and tracks of more than 23 mammal species were detected including 12 carnivore species. Lynx, fisher, and wolverine use of forest age classes and vegetation cover types east and west of the Continental Divide in GNP was determined during winter by counting tracks in snow along 175 transects in 3 different forest age classes and 6 different vegetation cover types. Stand age classes and cover types available along transects were described using Arcview GIS 3.1 software and raster-based analyses of 1981 Landsat MSS images. Cover types and stand age classes available along transects were compared to habitat characteristics at points where target species were observed using a chi-square goodness-of-fit test. Lynx, wolverine, and fisher did not use cover types as expected by availability. Lynx use of deciduous and dry coniferous forest types was significantly greater than expected while dry herb/shrub and mesic conifer cover types were used significantly less than expected ($P<0.01$). Fishers used deciduous and dry coniferous forest types more than both shrub cover types ($P<0.05$). Wolverines used both conifer cover types significantly less than expected while deciduous forest stands and dry herb/shrub were used significantly greater than expected ($P<0.01$). Lynx and fisher use of stand ages was also significantly different than expected ($P<0.05$). Both lynx and fisher frequented old stands (pre 1844) more than expected. Wolverine use of stand age classes was not significantly different than random. Lynx appeared to have a wide distribution east of the Continental Divide in GNP, but were rarely detected on the park's west side. Fisher and wolverine were detected on both sides of the Continental Divide, but most detections occurred on the park's east side. Mountain lions (*Felix concolor*) and coyotes (*Canis lupus*) were frequently detected during surveys and appeared to be limited to the lowest elevations in GNP. Their winter distribution does not appear to overlap that of lynx, fisher, or wolverine extensively.

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BACKGROUND

Growing concern over the impacts of extensive logging and road-building in the old-growth forest ecosystems of the Pacific Northwest in the 1980s and early 1990s resulted in controversial federal protection for threatened species like the northern spotted owl (*Strix occidentalis*), marbled murrelet (*Brachyramphus marmoratum*) and Pacific salmon (*Onchorhynchus spp.*). More recently, concern over the degradation and fragmentation of forest habitats in the Rocky Mountains has focused attention on a group of largely overlooked forest carnivores associated with late-successional forests. Canada lynx (*Lynx canadensis*), fisher (*Martes pennanti*), wolverine (*Gulo gulo*), and marten (*Martes americana*), are mid-sized carnivores that have become rare at the southern end of their ranges in the conterminous United States. Traditionally referred to as fur-bearers because of their valuable pelts, local populations of these four forest carnivores were extirpated in many areas as a result of intensive trapping and habitat degradation. As harvest levels declined south of Canada, state wildlife agencies established trapping quotas or eliminated legal trapping. Often these measures came too late for the populations to recover or avoid regional extinction.

In 1994, uncertainty over the status of forest carnivores in the western United States prompted researchers and wildlife managers affiliated with the U.S. Forest Service to combine their knowledge of forest carnivores and present their findings in a conservation assessment

(Ruggiero et al. 1994). This assessment provided an overview of the species' ecology and biology, conservation status, and research needs. Although gaps in knowledge were revealed, existing research supported the interpretation that late-successional forest stands are essential components of forest carnivore habitat. Due to the inadequate information base and the reduced extent of late-successional forests, the report concluded that "the status of forest carnivores is itself uncertain." Factors that may have contributed to the decline in forest carnivore populations included 1) decrease in the amount of suitable habitat; 2) mortality and habitat fragmentation caused by roads and development; 3) impact from increased recreational use of wild lands; and 4) over-trapping (Ruggiero et al. 1994).

Forest Carnivore Ecology

With their disproportionately large, hairy feet, Canada lynx are well adapted to forested habitats with abundant snowfall. Lynx habitat generally is described as climax boreal forest with a dense understory of thickets and windfalls (Witmer et al. 1998). Advanced successional stages of forests and dense young conifer stands are often preferred habitats of lynx for denning and foraging respectively. Large amounts of woody debris for thermal and escape cover and minimal human disturbance are important features of den sites (Brittell 1989). Lynx generally forage in young conifer forests where their primary prey, snowshoe hare (*Lepus americanus*), is abundant. Late-successional forests with high horizontal cover may also be important foraging habitat if red squirrels (*Tamiascurus hudsonicus*) and snowshoe hares are present. Lynx habitat south of Canada is more heterogeneous and patchily distributed than source habitat in Alaska and Canada (Ruggiero et al. 2000). As a result, travel corridors between foraging and denning/resting habitats may be an important and overlooked habitat component. Travel cover includes contiguous vegetation cover over 2m tall (Brittell 1989), as lynx generally do not cross openings greater than 100 meters wide (Koehler 1990). Lynx have large home ranges, between 8 and 783 km^2, and have been known to conduct extensive exploratory movements during summers and during lows in the snowshoe hare cycle. These long-range movements may be important in maintaining genetic diversity at the population and meta-population levels (McKelvey et al. 2000a).

Unlike like lynx, fishers are not well adapted to traveling or hunting in deep snow and they generally occupy low to mid-elevation forests with high canopy closure and low average snow accumulation (Powell and Zielinski 1994). Old forest stands with high structural diversity near the ground provide fishers with important den and rest sites while early seral stands provide productive habitat for snowshoe hares. Like lynx, fishers use a mosaic of early and late-successional forest stages to meet their habitat and food requirements. However, the fisher's preference for mid to lower elevation forests and riparian woodlands ensures that there is little overlap in habitats used by these species (McKelvey et al. 2000a). Small patches of early seral vegetation interspersed within a matrix of relatively dense, late successional forest may be the habitat that provides the most diverse prey base for fishers (Witmer et al. 1998). Fishers are solitary and inhabit large home ranges averaging between 15 to 40 km^2. Fisher populations have been significantly affected by the fragmentation of contiguous, late-successional forests and excessive trapping especially in the southern and western portions of their range (Powell and Zielinski 1994).

Wolverines are wide-ranging carnivores that use a variety of habitats across elevational gradients including non-forested habitats in alpine and subalpine zones. When detected at lower elevations in NW Montana, wolverines exhibited a preference for mature to intermediate forests (Hornocker and Hash 1981). The collective knowledge of wolverine in the conterminous U.S. is scant and consists of only two studies (Hornocker and Hash 1981, Copeland 1996). Research suggests that the essential component of wolverine habitat may be isolation and absence of human disturbance (Banci 1994). Wolverines were apparently extirpated from most of Montana by 1920 due to over-trapping and secondary poisoning, but recovered through dispersal from Canada via Glacier National Park (Newby and Wright 1955). Wolverine appear to require large, isolated tracts of wilderness supporting a diverse prey base. Wolverines exhibit a distinct seasonal elevational pattern moving to lower elevations during the winter where they search for carrion on ungulate winter ranges (Hornocker and Hash 1981). A limiting factor to wolverine distribution may be the availability of suitable denning habitat (Copeland 1996). Female wolverine appear to require remote alpine cirques for denning and are especially sensitive to human disturbance during courtship, denning, and rearing of young (Magoun and Copeland 1998). The loss of large predators such as wolves and mountain lions from an ecosystem can adversely affect wolverines by reducing the amount of available carrion. Home ranges of adult wolverine are quite large, ranging from less than 100 km^2 to over 900 km^2 (Banci 1994). Wolverine populations in the lower 48 states are likely peninsular extensions of a more expansive Canadian population.

Because American martens prefer microtine rodents and squirrels and rarely prey on hares, they are the forest carnivore species most closely associated with late-successional forests. Martens prefer mature and old-growth subalpine fir, spruce-fir and cedar-hemlock forests for denning, hunting, and protection from predators. Mesic forest types with a well-developed understory of grasses and forbs support high numbers of small mammal prey, and abundant fallen trees and limbs provide sites for denning, resting and foraging, habitat features that are especially important in winter (Buskirk and Powell 1994). Research conducted in Glacier National Park (GNP) indicated that the abundance of small mammals was directly associated with the abundance, physical condition, dispersal, and density of the martens under study (Burnett 1981). Like Canada lynx, martens are well-adapted to habitats characterized by snowy winters, and substantial snow cover. Recent research suggests that interior forest conditions may be an essential component of suitable breeding habitat for martens (Hargis et al. 1999). Destruction, degradation, and fragmentation of refugia is a serious threat to the viability of marten populations in the lower 48 states (Joslin and Youmans 1999). Because of their relative abundance, close association with contiguous, late-successional forests, and vulnerability to trapping, marten are considered indicators of the health of forest ecosystems. Marten home ranges vary as a function of sex, geographic area, and prey abundance, but are generally considered large for an animal of its size (1-16 km^2) (Buskirk and Ruggiero 1994).

Conservation Status

On April 24, 2000, the Canada lynx was listed as a threatened species in the coterminous United States. The U.S. Fish and Wildlife Service (USFWS) concluded that the population was threatened by human alteration of forests, low numbers as a result of past overexploitation, expansion of the range of competitors, and elevated levels of human access into lynx habitat (USDA, USDI 2000). Critical habitat for the species has not been designated or proposed.

Concurrent with the listing process, a national interagency *Canada Lynx Conservation Assessment and Strategy* (Ruediger et al. 2000) was developed to provide a consistent and effective approach to conservation of the species. All federal land management agencies, including the National Park Service, were participants. The *Canada Lynx Conservation Assessment and Strategy* identifies 17 risk factors that could adversely affect lynx mortality, productivity, and movements (Ruediger et al. 2000). Within GNP, the primary risk factors for lynx are: wildland fire management policies that preclude natural disturbance processes, roads and highways, winter recreational trails, habitat degradation by non-native invasive plant species, incidental or illegal shooting and trapping, competition or predation as influenced by human activities, and human developments that degrade and fragment lynx habitat.

The U.S. Forest Service and U.S. Bureau of Land Management have entered into conservation agreements with the USFWS, agreeing to consider conservation measures in the *Canada Lynx Conservation Assessment and Strategy* when designing and implementing activities that might affect lynx or their habitat. The National Park Service is currently in the process of crafting a Conservation Agreement for Canada Lynx with the USFWS. Potential lynx habitat has not yet been delineated in Glacier National Park due to inadequate vegetation and snow depth data for the park. Although the National Park Service has not yet signed the Conservation Agreement for the Canada Lynx, Glacier National Park has agreed to consider the recommendations in the *Canada Lynx*

Conservation Assessment and Strategy prior to undertaking any new activities in lynx habitat.

Since 1975, Montana's lynx harvest declined dramatically, and lynx abundance was considered very low (MDFWP 1990, Tanimoto and Garton 1993). Although knowledge of lynx ecology in the lower 48 states has not increased significantly since the U.S. Forest Service completed its assessment in 1994, new studies have been initiated in Montana, Wyoming, and British Columbia and a major reintroduction program is under way in Colorado. These efforts are all addressing the lack of knowledge of lynx ecology,

> "...there is a need for the most basic information on habitat relationships, at any spatial or temporal scale and at any level of measurement. Virtually any new data on habitat relationships involving lynx in the western conterminous 48 states would be a substantive increase in knowledge" (Ruggiero et al. 1994).

The state of Montana classifies marten, fisher, and wolverine as fur-bearers and closely monitors trapping of these species. While upwards of 800 marten are harvested annually in the state, the trapping of wolverine and fisher is limited and few animals are recorded harvested (MDFWP 1998). Until lynx were federally listed as a threatened species in 2000, a statewide quota of two animals was enforced. Region 1 of the U.S. Forest Service has designated both the fisher and wolverine "Sensitive Species", while the marten is considered a "Management Indicator Species." Fisher and wolverine are also listed as state "Species of Special Concern" by the Montana Natural Heritage Program.

Due to extensive trapping, fishers were apparently extirpated from Montana, as there are no trapping records for the state from 1920-1960. Because of their value as a furbearers and predators of porcupines, fishers were reintroduced into western Montana from British Columbia in 1959/60 (Weckwerth et al. 1968). Montana's fisher population was again augmented between 1989 and 1992, when 110 fishers were transplanted into northwestern Montana from the midwestern U.S. (Heinemeyer and Jones 1994). Although fishers have been re-established in the state, they are considered uncommon and patchily distributed. The USFWS was petitioned by conservation groups in the 1990s to list both the fisher and wolverine as endangered species under the Endangered Species Act (1973), but cited the lack of information in their decision not to do so. A lawsuit regarding listing of the wolverine has recently been filed by conservation groups.

Although the status of the fisher in the western U.S. is poorly known, it is generally perceived to be "precarious and declining" (Powell and Zielinski 1994). Marten populations are regarded among the least compromised of the four species discussed here, though the current range of the species is reduced from historical limits in the U.S. (Buskirk and Ruggiero 1994). Wolverine populations in Montana are considered "healthy and thriving" and appear viable given their continuity with populations in Canada (Witmer et al. 1998). Because wolverine have experienced a significant range contraction in the last century, occur at low densities, and depend on habitats in remote areas with little human presence/access, the viability of this species outside of Canada, Alaska and Montana is uncertain (Banci 1994). Specific information needs for these four forest carnivores are extensive and have been described in detail by Ruggiero et al. (1994). Throughout the current ranges of these species, there is still a need for the most basic information on distribution, abundance, density, habitat use, and population dynamics before effective conservation strategies can be developed (Ruggiero et al. 1994).

INTRODUCTION

Historic Status of Forest Carnivores in GNP

Early sightings and anecdotal information on the distribution and relative population status of forest carnivores in Glacier National Park were described in *Wild Animals of Glacier National Park* (Bailey and Bailey 1918). At the time, lynx were considered "more or less common throughout the Glacier Park region." In 1895, lynx tracks were seen at St. Mary Lake and one animal was caught in a trap near timberline just north of the lake. Fishers were considered rare in any part of the U.S. in 1918, and only "a few" were reported to be "holding their own" in the park region at the time. Many old trappers reported never taking any fisher in the region, but two were trapped in the Many Glacier area. Wolverine trapping records existed for both the eastern and western slopes of the park region prior to 1918, but at that time, the authors concluded that there were none left in the park (Bailey and Bailey 1918). Marten were considered "numerous or very common" and were much admired by trappers in the area. According to the authors, "For at least half a century the park region has been famous for the number of martens caught each year by trappers...The animals are reported to be more common on the west slope of the mountains than on the east, but this is probably because the timber there is more dense and extensive." Bobcat (*Lynx rufus*) were "not common" but were occasionally detected at lower elevations. Mountain lions (*Felis concolor*) were considered "abundant" on the west side of the park, but scarce on the east side. Gray wolves (*Canis lupus*) were known to range along the eastern edge of the park and in the North Fork Valley and were occasionally observed in the park's interior. Coyotes (*Canis latrans*) were considered "surprisingly common in the elevated interior" of the park, and were also present throughout lowland areas (Bailey and Bailey 1918). Red fox (*Vulpes vulpes*) were "occasionally seen in Glacier Park" at lower elevations east and west of the Continental Divide. Swift fox (*Vulpes velox*) were "common over the plains along the eastern edge of the park," but there were no records of this species from inside the park.

Past Research

While GNP's large carnivores such as mountain lions, grizzly bears (*Ursus arctos*), and gray wolves have been well studied, little research has focused on the park's smaller carnivores. Of the four forest carnivores discussed above, only marten have been the subject of research in GNP (Hawley 1955, Jonkel 1959, Burnett 1981). Intensive live-trapping for marten in the North Fork of the Flathead drainage from 1953 to 1958 as part of a marten ecology project did not result in the unintentional trapping of any fisher although several other similarly-sized mammals were trapped (Jonkel 1959). If any fisher were present on the study area during the study, they were not detected by researchers (C. Jonkel, Great Bear Foundation, pers. comm.) A telemetry study of marten conducted between 1979 and 1980 in the same study area, also resulted in no accidental captures of fisher (Burnett 1981). Besides the research on marten in the North Fork, there have been no intensive studies of lynx, fisher, or wolverine anywhere in GNP. Shea (unpubl. 1976) conducted systematic track surveys in the North Fork of the Flathead River section of GNP as part of a winter ecological assessment and documented the presence of lynx, fisher, marten, and wolverine and several other species. Shea (unpubl. 1976) also described the relative abundances of these species based on sightings by park rangers and local residents. According to Shea (unpubl. 1976), marten, fisher, and wolverine "have evidently become more numerous since 1910." Apparently, lynx numbers "remained quite constant."

A pilot tracking project was conducted by GNP in the spring (March-May) of 1994 to determine whether rare and uncommon forest carnivores still occurred in the park, and to assess the feasibility of initiating more intensive survey efforts (Yates, unpubl.1994). Despite limited time and sub-optimal snow conditions, Yates documented the occurrence of marten, fisher, lynx, wolverine, and numerous other species during the pilot survey. Additional detection surveys were recommended due to the paucity of information regarding forest carnivores in GNP and their uncertain status in the western U.S. (Yates unpubl. 1994). Yates (unpubl. 1994) also summarized park-wide sightings of forest carnivores that occurred between 1965 and 1994 from GNP's Wildlife Observation Database. The majority of GNP wildlife sighting records in the Wildlife Observation Database were not systematically collected and have not been assessed for reliability or verification. Therefore, the utility of this database for delineating historic distribution or identifying population trends is limited.

Study Purpose and Objectives

According to the *National Park Service Management Policies* (2001), "the Service will survey for, protect, and strive to recover all species native to national park system units that are listed under the Endangered Species Act." In addition, the NPS "will both pro-actively conserve listed species and prevent detrimental effects on these species." By fall 1998, it had become increasing apparent that the USFWS would soon decide to protect the lynx under the federal Endangered Species Act. Given the lack of information on the status and distribution of lynx in GNP and the National Park Service's management policy requiring the conservation of listed species, park biologists and managers acquired funding for lynx monitoring and initiated a winter survey program.

This study was conducted during two winters (1998-2000) and was designed to provide information useful to GNP, MDFWP, and the USFWS. The purpose of the project was to collect baseline data on the presence and distribution of rare forest carnivores and their prey. Intensive efforts were made to survey every major drainage within GNP in a systematic and repeatable manner, and to describe in sufficient detail habitat features associated with track detections for fisher, lynx, wolverine and their prey. The study objectives were to:

1) develop a winter track survey protocol for use in GNP;
2) document the presence and winter distributions of lynx, fisher, wolverine, marten, and other species;
3) describe habitat use by target species where they were detected;
4) determine the relative abundance of forest carnivore prey species, particularly snowshoe hare and red squirrel;
5) deploy remote-sensing cameras as available to provide photographic evidence of forest carnivore occurrence.

STUDY AREA

The entire park, which includes both the east and west sides of the Continental Divide, was chosen as the study area for this survey. GNP encompasses more than 410 000 ha (4100 km^2) along the Continental Divide in the Rocky Mountains of Montana (Figure 1). Extended periods of glaciation carved out a rugged landscape of steep mountain peaks reaching over 3030 m and deep, lush valley bottoms extending down to 910 m. The uppermost crest of the Continental Divide lies above treeline, leaving one-third of the park extremely difficult to access during winter months. Heavy snowfall, strong winds, steep terrain and sparse vegetation create frequent avalanches at upper elevations. Lack of forest cover, an essential component of forest carnivore habitat, and avalanche danger were two reasons these areas were excluded from survey efforts.

Vegetative landcover types in the park include: dry herbaceous (plants and shrubs that grow in dry areas such as fescue grasslands (*Festuca spp.*) – approximately 31 188 ha); mesic herbaceous (plants and shrubs that grow in wet areas, including riparian areas, wet meadows, alpine meadows – approximately 19 757 ha); deciduous trees and shrubs, such as aspen (*Populus tremuloides*), cottonwoods (*Populus trichocarpa*) (26 274 ha); dense, mesic coniferous forests, including Englemann spruce (*Picea engelmannii*), western larch (*Larix occidentalis*),

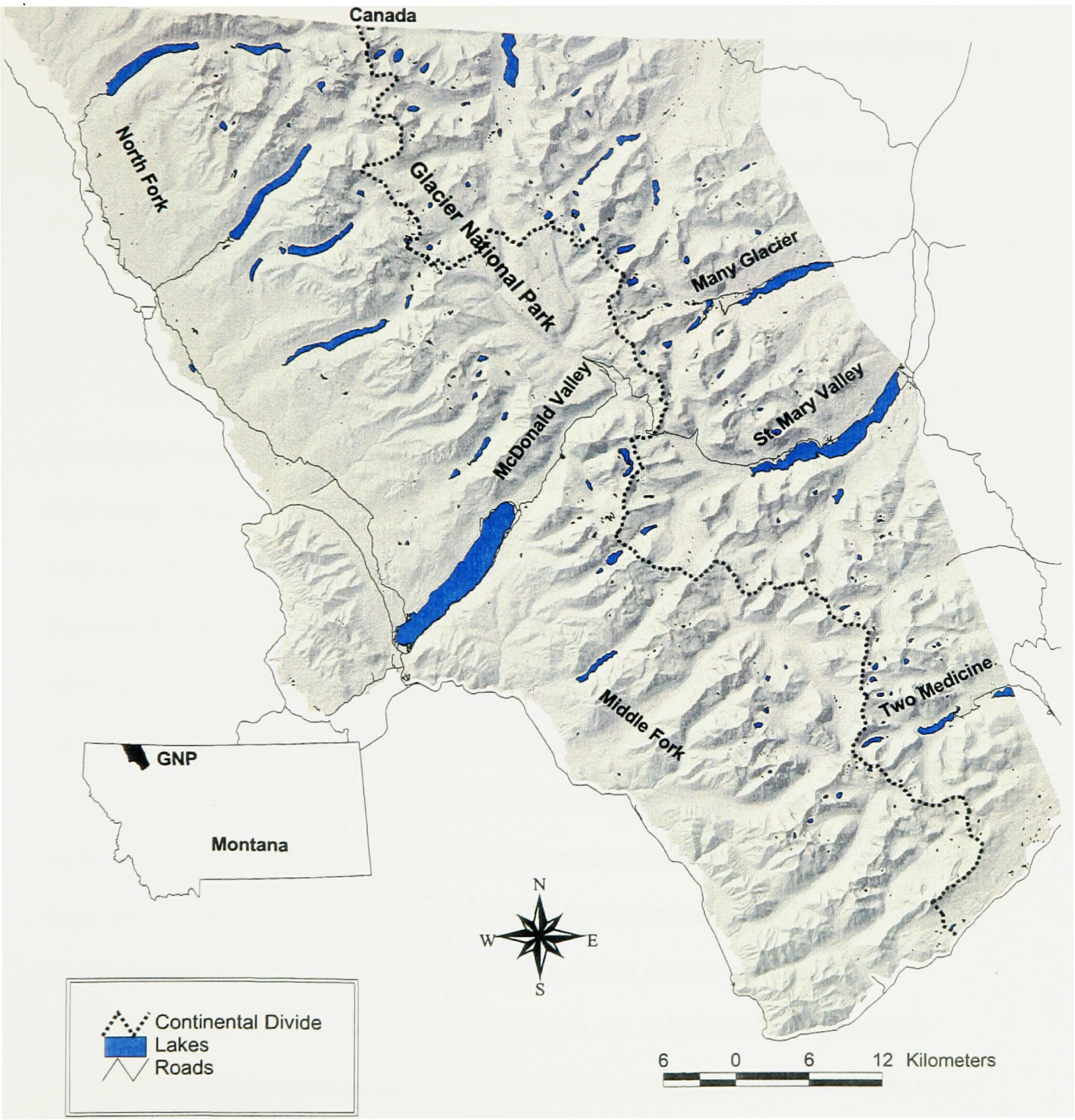

Figure 1. Glacier National Park forest carnivore detection surveys study area, 1998-2000.

sub-alpine fir (*Abies lasiocarpa*), western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*) (135 547 ha); open, dry coniferous forest, including ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), limber pine (*Pinus flexilis*) (65 051 ha); and barren rock, snow, and ice (120 741 ha) (GNP 1990).

West Side

The west side of GNP can be divided into three distinct areas: (1) the North Fork of the Flathead River (NFFR) and its tributaries, (2) the McDonald Valley, and (3) the Middle Fork of the Flathead River (MFFR) and its tributaries. The NFFR area extends from the Canadian border to the south end of the Apgar mountains forming the western border of GNP. The NFFR flows southeast from Canada and joins the MFFR at the south end of the Apgar mountains with an elevation change from 1283 m at the border to 1024 m at the confluence. The climate of this area can best be characterized as transitional between a northern Pacific coastal type and a continental type. Snow normally covers the area from November to April with a mean annual snowfall of 305 cm and an average maximum daily snow depth of 65.4 cm at Polebridge, Montana for 1951-1980. Summers are generally short and mild, while winters are long and cold (Ruth et al. 1994). Two dirt roads parallel the east and west sides of the NFFR providing access to all of the river's tributaries.

The road along the NFFR inside GNP is closed to vehicle traffic in the winter, but skiers access the area via a bridge at Polebridge.

The wet valley bottom sites of the NFFR are dominated by black cottonwood and spruce. Dense stands of lodgepole pine dominate much of the area. Other fire-dependent species such as western larch, western white pine (*Pinus monticola*) and ponderosa pine are also common on drier and warmer sites. Mixed coniferous stands of lodgepole pine, western larch, sub-alpine fir and Douglas-fir also prevail (Kunkel 1997). Abundant meadows, patches of native fescue grassland, and riparian areas are dispersed throughout the NFFR area. Numerous valleys containing fast-moving creeks and deep glacial lakes extend southwest from the Livingston Range towards the NFFR creating a topography that is more gentle and rolling than other areas of GNP.

Because of a rain shadow cast by the Whitefish range to the west, the NFFR valley is drier than both the McDonald and MFFR valleys. Recent, large fires and smaller prescribed burns have contributed to the diversity of habitats and seral stages found throughout the North Fork valley (Rockwell 1995). Historically, NFFR fire intervals ranged from 15-70 years in the lower elevations, but aggressive fire suppression over the last 100 years has greatly altered this pattern. Before suppression, fires were frequent, small in area, and low in intensity. The result being a mosaic of age class patterns (Barrett 1986). Factors associated with fire suppression have altered the historic fire regime of the NFFR valley so that the area in now characterized by large-scale, stand replacing fires.

The McDonald Valley is unique in that it is the widest and deepest valley of any tributary on the west side, and it contains Lake McDonald, one of the largest lakes in the park. McDonald Creek originates near the Continental Divide at an elevation of 1859 m and drops 898 m in 35.4 km before emptying into Lake McDonald. Although the climate of this area is a modified north Pacific coast type, topographical influences including valley-ridge configurations, elevation, lake effect, aspect and exposure combine to produce extreme variation in weather over short distances (Kuchel 1974). At the south end of the valley, the West Glacier townsite (elevation 961 m) receives an average of 76.2 cm of precipitation annually. Along the Continental Divide, gauges at Grinnell Glacier (elevation 1950 m) indicate an annual average of 305 cm (Kuchel 1977). Most of the precipitation occurs during two periods: between November and February as winter snowfall, and between May and July as spring rain.

Maritime climatic influences create a complex of moist, cool sites permitting the establishment of plant communities more typical of western Washington and Oregon. Different phases of western redcedar and western hemlock habitat types dominate the southern reaches of Upper McDonald valley. Dominant tree species along the upper reaches of McDonald Creek include Engelmann spruce and Douglas-fir.

Numerous avalanche chutes and a 1967 fire have left many areas of the valley sparsely vegetated. Along streambanks, willow (*Salix* spp.), alder (*Alnus* spp.) wild rose (*Rosa* spp.), Hawthorn (*Cretaegus douglasii*) and red-osier dogwood (*Cornus stolonifers*) predominate (Kuchel 1977). Fires in this moist environment are infrequent, occurring only once every 300-400 years. But they are usually large and intense given the build up of fuels.

The Going-to-the-Sun Road, Glacier Route One, parallels the east side of the lake and creek. Numerous parking pullouts and two campgrounds line the road as it winds its way up to Logan Pass and over the Continental Divide. Nearly two million people a year visit GNP, most making the drive over Logan Pass. Although the road is closed to vehicles beyond Lake McDonald in the winter, many visitors ski or snowshoe this route. Consequently, it is one of the most intensively visited areas in the park.

The MFFR portion of the study area lies in the southwestern corner of GNP, and is one of the most remote areas in the park. Topographically, the area is bounded on the northwest by the Belton Hills and Snyder Ridge; on the north and northeast by the Continental Divide; on the south and southeast by the MFFR and Bear Creek. The MFFR lies in a long, steep and narrow canyon that forms the south western boundary of GNP. United States Highway 2 parallels the river and its tributary, Bear Creek, and remains outside of GNP between West

Glacier and Walton. The absence of bridges or roads across the MFFR into GNP between Walton and West Glacier makes the MFFR one of the least visited areas in GNP. This portion of the study area is adjacent to the Great Bear and Bob Marshall Wilderness areas forming the largest wilderness complex south of Canada.

The MFFR area is densely forested with fire-initiated, even-aged stands of lodgepole pine and western larch covering most of the area. The potential climax species in this area are Engelmann spruce and sub-alpine fir, but frequent fires have limited the distribution of these species. Pockets of western redcedar/ western hemlock habitat types persist in cool, moist sites along tributaries of the MFFR between Lincoln Creek and Nyack Creek. Marias Pass (elevation 1585 m) is a broad, forested saddle along the Continental Divide and just above the headwaters of Bear Creek. Most of the saddle is covered by a dense, but stunted forest of lodgepole pine. This area is also frequently subjected to high winds making it similar to the east side of GNP. Mean annual precipitation at Walton (elevation 1146 m) is about 102 cm, making it considerably more moist than the NFFR. The historic fire regime of the MFFR region is a long fire interval/ total stand replacement pattern. Although fire suppression has been intensively practiced over the last 100 years, it has not measurably affected MFFR stands given their long fire interval of 150-300 years (Barrett 1986).

East Side

The east side of GNP is the northern most extension of what is known commonly as the Rocky Mountain Front. It is where the steep and rugged Lewis Range of the Rocky Mountains abruptly meets the rolling prairie. The east side boundary is line roughly following the edge of the mountains from the Canadian border to near the town of East Glacier. To the east of the boundary lies the Blackfeet Indian Reservation; to the west lies the Continental Divide; to the north lies Alberta and Waterton Lakes National Park; and to the south lies the Lewis and Clark National Forest.

The east side of GNP can be divided into four areas based on major river drainages. Proceeding north from Marias Pass to the Canadian border, these areas are: 1) Two Medicine River, including Summit and Cut Bank Creeks; 2) Saint Mary River, including Swiftcurrent and Otatso Creeks; 3) Belly River, including Lee Creek; and 4) Waterton River. The east side of GNP lies in a transition zone between the Northern Rocky Mountain- and Northern Great Plains ecosystems (Barrett 1997), and between the sharply contrasting Pacific Maritime- and Continental climatic regimes (Finklin 1986). From 1965 through 1985, the towns of Saint Mary and East Glacier received a mean annual precipitation of 66.7 and 77.0 cm, respectively, which fell mainly during November-January and April-June. Snow typically covered the area from December through April, with mean annual snowfalls of 409 and 490 cm, respectively, for Saint Mary and East Glacier. The mean maximum daily snow depth at East Glacier was 96.0 cm in February and March (Finklin 1986). During winter, the interaction of Arctic and Pacific storm fronts causes warm air masses to be alternately forced out of and drawn into the Rocky Mountain Front area, generating very strong "chinook" winds that typically blow out of the southwest. In general, the east side of GNP is drier than the west side and experiences more extreme temperature fluctuations.

Elevations along water courses range from 1356 m on Saint Mary River to numerous alpine lakes and creek headwaters between 1850 m and 2100 m. Lower elevations along the Rocky Mountain Front are characterized by fescue-dominated meadows and climax aspen groves. Mid-elevations contain a relatively narrow band of coniferous montane- and subalpine forests, above which lie extensive alpine rocklands (Arno 1979). Montane forests are dominated by lodgepole pine, Douglas fir, subalpine fir and Engelmann spruce, with dry rocky sites often occupied by limber pine. Subalpine forests consist primarily of subalpine fir and Engelmann spruce, with some stands of lodgepole or whitebark pine (*Pinus albicaulis*) (Barrett 1997).

The morainal foothills of GNP's east side historically experienced a wildfire once every 10 to 19 years. Fires in these foothills were of mixed severity, with major fires developing about every 35 years. Since about 1940, fire suppression has lengthened the fire interval to 60 years

(Barrett 1993). Sites dominated by mesic coniferous forests historically experienced less frequent but more severe stand-replacement fires. While historic fire intervals for these mesic sites on GNP's east side were 210 to 350 years, today's fire cycle is approximately 873 years (Barrett 1997).

METHODS

Selection of Survey Methods

Canada lynx, fisher, wolverine, and marten are relatively secretive species that have proven difficult to study because they occur at low densities, are primarily nocturnal, have inconspicuous mating behavior, leave little sign, and avoid human activity (Zielinski and Kucera 1995). Historically, managers assumed that carefully regulated trapping programs would provide the data necessary to monitor these species and detect declining populations. As lynx, fisher, wolverine, and marten have declined in their significance to the fur harvest south of Canada, alternate monitoring methods were required to detect changes in distribution and abundance.

Zielinski and Kucera (1995) were the first to compare survey methods for the collection of data regarding the occurrence and distribution of lynx, fisher, wolverine, and marten. They identified three unobtrusive methods of detection that offered ease of use, effectiveness, and economy: remote cameras, track plates, and snow tracking. Of the three methods described only two, snow tracking and dual sensor remote cameras, had been proven effective at detecting all four species. A comparison of three different methods for detecting forest carnivores in Yellowstone found snow tracking to be the most effective (Steve Gehman, Wild Things Unlimited, pers. comm.). Bull et al. (1992) in eastern Oregon found snowtracking to be both effective and relatively inexpensive for detecting marten Foresman and Pearson (1995) compared the efficacy of the three survey methods described by Zielinski and Kucera (1995) in the Bitterroot Mountains of westcentral Montana. The researchers concluded that remote-sensing cameras provided "the most unambiguous information, photographic evidence of a species presence," but they also acknowledged that the costs associated with this method were a significant drawback. The method Foresman and Pearson (1995) found least effective at providing reliable information was snow tracking, but they conducted their study in a region where snow conditions were generally poor and unreliable. They noted that the effectiveness of snow tracking is limited by its dependence on ideal snow conditions and well-trained technicians with considerable experience. When both these criteria are met, the authors concluded "this method will provide useful information" (Foresman and Pearson 1995).

Snow tracking was selected as the method to be used in the GNP forest carnivore survey, due to its proven effectiveness in detecting all four forest carnivore species and its relative low cost. Pilot track surveys conducted in GNP by Yates in 1994, and confidence in the high quality and reliability of snowfall in the study area combined to make snow tracking a sound choice. Winter track surveys were also considered valuable for the information they could provide on non-target species that are of management concern (e.g., moose, mountain lions, grizzly bears, wolves, etc.).

In addition to delineating distribution, occurrence data can also be used to describe habitat use by measuring relative habitat associations. Systematic track counts along established transects have been used to describe snowshoe hare habitat use and relative densities and have been correlated with lynx presence (Litvaitis et al. 1985, Koehler et al. 1990, Koehler 1990). Habitat use of fox, lynx, weasels, marten, wolves, and other carnivores has also been described from track distributions (Davey 1997, Oksanen et al. 1992, Dekker 1989, Koehler et al. 1990). Habitat use should not be confused with habitat requirements (i.e., the resources or environmental features required to maintain population viability). According to Ruggiero et al. (1994),

> "the existence of an animal in some environment at one point in time says little about what the individual requires for persistence. Accordingly, presence/absence data is, by itself, unreliable as the basis for inference about habitat requirements."

Habitat requirements can only be inferred when data on habitat use is combined with data on population size, structure, and age-specific reproductive and survival rates (Ruggiero et al. 1994).

Survey Methods and Protocol

The snow tracking detection method described by Halfpenny et al. (1995) in Zielinski and Kucera (1995) was adapted for the GNP forest carnivore surveys. Halfpenny et al. (1995) emphasized that snow tracking is an effective method for determining presence and delineating distribution only. Using the results of detection surveys to describe population status and trend is not recommended by the authors. They also emphasize that non-detection does not mean absence. The snow tracking and track observation forms developed by Halfpenny et al. (1995) have become the standard method for documenting the results of snow tracking surveys, and were used in the GNP survey (Appendix A). As Halfpenny et al. (1995) do not provide a detailed protocol for enumerating tracks of non-target species, a track count protocol was developed and tested for GNP. The input of researchers conducting track surveys throughout the Rocky Mountains was solicited to facilitate this process. The protocol developed for GNP closely follows that used by the MDFWP in an effort to standardize the data collection methods and extend the utility of the information gathered (Appendix B). Significant effort was made to employ and train competent and experienced field technicians, and to develop standardized sampling procedures to minimize observer bias.

Track surveys were conducted in winter (between the months of November and April) with the intent of surveying every major drainage in

GNP while snow conditions permitted. Halfpenny et al. (1995) recommended that the survey area be divided into 6.4-km^2 sample units and that a minimum of 10 km be traversed by foot through preferred habitats within each sample unit. The amount of effort (i.e., cost) required to conduct such a thorough survey has deterred many wildlife managers from completely adopting this survey methodology. In fact, most managers have modified the approach recommended by Halfpenny et al. (1995) to include only established roads and trails as track transects (Brian Giddings, MDFWP, pers. comm., Foresman and Pearson 1995). Existing trails and closed roads only were surveyed in GNP because of efficiency of travel, safety, repeatability, and logistical feasibility. Off-trail and off-road areas were not sampled. The goal was to survey each transect a minimum of three times or until target species were detected. Survey routes were not randomly selected. Instead, routes were prioritized according to accessibility, historical records, and habitat suitability. Routes were selected that included topographical features frequently used by lynx and other species: valley bottoms, upland areas, ridges, and saddles (Koehler 1990). Survey routes spanned a wide elevation gradient (between 910 and 2210 m), and included a range of slopes and aspects. Optimal tracking conditions occur 24 to 72 hours after a snowfall, but numerous routes were surveyed immediately after or during snowfall. This was due to the availability of technicians and the frequency of multi-day, back-country surveys during which decisions about whether to survey were determined by imperative rather than by snow conditions.

Most track surveys were conducted on skis and snowshoes, but early in the winter conditions permitted tracking from a vehicle. All wildlife tracks encountered along track transects were recorded in field notebooks and later transcribed to snow tracking and track observation forms developed by Halfpenny et al. (1995) and GNP. Notable detections of uncommon species (lynx, fisher, wolverine, mountain lion, wolf and moose) were entered into GNP's wildlife observation database (WORF). All bear sightings were entered into the Bear Information Management System (BIMS) database. The exact time (24H) and Universal Transverse Mercator (UTM) location were recorded for all tracks of lynx, fisher, wolverine, wolf, mountain lion, grizzly bear, black bear and moose. Tracks of marten were so numerous that time did not allow for collection of precise locations for each detection.

The tracks of more common species, like marten, were recorded at intervals of approximately one kilometer. The difficulty of distinguishing individual sets of ungulate tracks along high-use trails, led to their being recorded only as present (with no tally of tracks) in most instances. Tracks of smaller prey animals (snowshoe hare, red squirrel, grouse, vole, mouse and shrew), marten and the smaller weasels (long-tail, short-tail, least) were tallied and recorded at each stop. All three species of smaller weasel were simply recorded as "weasel" as a positive identification based on track size alone was virtually impossible given significant size overlap. Different methods for tallying prey were tested throughout the field season. Estimating the number of individuals of a particular species using average home range size and density was proposed as a method. But, this is too subjective. Instead, a count of all tracks crossing the route was concluded to be the best index of relative abundance. Field experimentation led to the preferred method of counting only those tracks spaced at least 10-m apart from the last recorded track of the same species (the same method used in MDFWP surveys). To make the data comparable, the track tally of each prey species was divided by the number of days since the last snowfall for each survey route. If the observer recorded the time since last snowfall in hours or half-day intervals, the value was rounded to the nearest whole number of days; values ranged from 1 to 6 days post snowfall.

Tracks of lynx, fisher, wolverine, and wolf were measured and photographed to provide verification of the identification. Multiple measurements of track size, stride and straddle were taken and averaged according to the method described by Halfpenny et al. (1986). Due to the significant degree of sexual dimorphism among mustelids, tracks of marten and fisher can be very difficult to distinguish in the field. A "2 ¼-inch" rule was applied for distinguishing fisher from marten tracks: only fresh or well preserved mustelid prints measuring 2 ¼ inches or greater in width were identified as fisher. Using this conservative standard, some female fishers were likely classified as martens, thus under-representing fisher presence in the study area.

Snow tracking quality (STQ) was also evaluated when tracks were recorded. STQ ratings are described by Halfpenny et al. (1995). Each time tracks of a target species were encountered, habitat features were measured and described. Dominant tree species were listed and the vegetative structure class was determined from an ocular estimation. Five vegetative structure classes were used: grass/forb, shrub/seedling, sapling/pole, mature and old-growth (Hoover et al. 1984). Under-story was described in terms of density (open, moderate, and dense).

All track detections for lynx, fisher, and wolverine were plotted on USGS 7.5 minute topographic maps and entered into a computer database for later entry into a Geographic Information System (GIS). Distribution maps for lynx, fisher, and wolverine, were created from the occurrence data using Arcview GIS Version 3.1 software (ESRI 1998).

Remote-sensing Cameras

Two remote-sensing camera systems were used for the purpose of obtaining photo-documentation of lynx and other rare species. Remote camera stations consisted of a Trailmaster Passive Infrared Trail Monitoring System (TM500) and a lure or other attractant. The TM500 is a dual-sensor remote camera system that consists of an automatic 35-mm camera modified to be activated by a microwave motion and a passive infrared heat sensor. The TM500 had been field tested and proven reliable and lightweight (Zielinski and Kucera 1995). An Olympus Infinity Mini DLX camera and the TM500 dual-sensor unit were housed in a metal ammunitions case and suspended approximately 5 ft. above the ground on a tree trunk. The box was secured to the tree with nails, duct tape, and/or plumber's tape.

Both olfactory and visual attractants were used at each remote camera site. A scented liquid lure was poured over the end of a log or stump or on a small piece of carpeting nailed to the trunk of a tree approximately 10-11 feet in front of the mounted camera system. Catnip was also used as a scent lure. Aluminum pie plates suspended from a tree branch were used as visual attractants to encourage the curiosity of felids. The protocol of Zielinski and Kucera (1995) was followed, and the camera stations were checked every 7-14 days to replace batteries and film and reapply the scent lure. All tracks in the area of the camera stations were also recorded at this time. Latency to detection (LTD) times have been estimated at 30 days for lynx, fisher, wolverine, and marten (Foresman et al. 1995). Location of the cameras was determined by 1) presence of target species' tracks, 2) accessibility for field technicians and 3) avoidance of human disturbance and vandalism. Photos of target species were documented as detections and plotted on USGS 7.5 minute topographic maps and entered into a computer database for later entry into a Geographic Information System (GIS). Camera stations were used principally to photo-document the presence of target species already detected during snow tracking.

Habitat Analysis

Most habitat features were measured in the field, but some (i.e., land cover type, slope, stand age) were described and analyzed using Arcview 3.1 GIS software (ESRI 1998). Slope was derived at each detection point for lynx, fisher, and wolverine from a USGS 30 m Digital Elevation Model (DEM). A raster-based analysis of Landsat MSS images (1981) developed by GNP identified 10 land cover types within the study area: 0) unclassified; 1) herb/shrub dry; 2) herb/shrub mesic; 3) deciduous tree/shrub; 4) conifer forest, dense, moist; 5) water; 6) barren; 7) snow; 8) shadow; and 9) conifer forest/dry (GNP 1990). Cover type polygons classified as snow, shadow, and unclassified were dropped from the analysis as no lynx, fisher, or wolverine were detected in these cover types. Likewise, our track transects did not adequately sample these cover types. The water cover type was also excluded from statistical analysis due to the low expected values that resulted. Habitat features such as dominant tree species and vegetative structure class that were measured in the field were cross referenced with GIS data on land cover types and fire history information to get the most accurate description of the physical features present at the detection points. Habitat availability and use were analyzed at the stand level. Cover types available along transects were determined from an analysis of 8300 computer generated points spaced 100 m along the survey routes. Cover types present along transects were compared to cover types where target species were observed. Habitat use as described here refers to the relative occurrence in certain cover types during the winter. I tested the hypothesis that detected use of cover types by lynx, fisher, and wolverine was different from random at $P < 0.05$ using a chi-square goodness-of-fit test. I followed the recommendations of Ott (1984) and Neu et al. (1974), and excluded categories from analysis when expected values were <1 (i.e., water, unclassified, snow, and shadow). Confidence intervals for each observed habitat category were calculated according to the methods of Neu et al. (1974) in order to detect preference or avoidance of individual habitats. Neu et al. (1974) stated that a chi square test may be used in cases where more than 20% of all categories contain less than 5 expected observations as long as the average (over all categories) expected observation is 6 or more (for the 0.01 level of significance of the test).

The relative occurrence of target species in certain stand age classes was also examined. Vegetative structure class field measurements were combined with a raster-based GIS layer of forest stand age classes and fire history descriptions. This GIS layer and database were developed between 1986 and 1997 by GNP and a private consultant using 1981 Landsat MSS images and ground-truthing (GNP 1997). For this analysis, stand age classes were placed into 6 categories: 1) single age young (post 1910); 2) single age middle (1844-1910); 3) single age old (pre 1844); 4) multi age young (post 1910); 5) multi age middle (1844-1910); and 6) multi age old (pre 1844). Multi age stands were classified according to the age class of the dominant component. Stand age classes present along transects were compared to the stand age classes where target species were observed using the same methodology described for the cover type analysis.

A use-availability analysis was not performed for aspect, understory density, and elevation as the exact proportion of each habitat category (for aspect, understory, and elevation) along transects could not be determined. Descriptive statistics alone were performed on these data.

RESULTS

Summary of Effort

During the winters of 1998/9 and 1999/2000, 175 track surveys over 604.6 km of trails (246.5 km east side and 358.1 km west side) were conducted by crews of GNP wildlife technicians and volunteer assistants for a total of 1525.1 km surveyed (875. 8 km on the west side and 649.3 km on the east side) (Figure 2). Of the 175 track surveys, 81 surveys were conducted on the east side and 94 surveys were conducted on the west side. A total of 73 transects were surveyed (0-4 replicates annually). Individual transects ranged in length from 2-13 km. Total time for sampling all transects was 731.2 hrs.

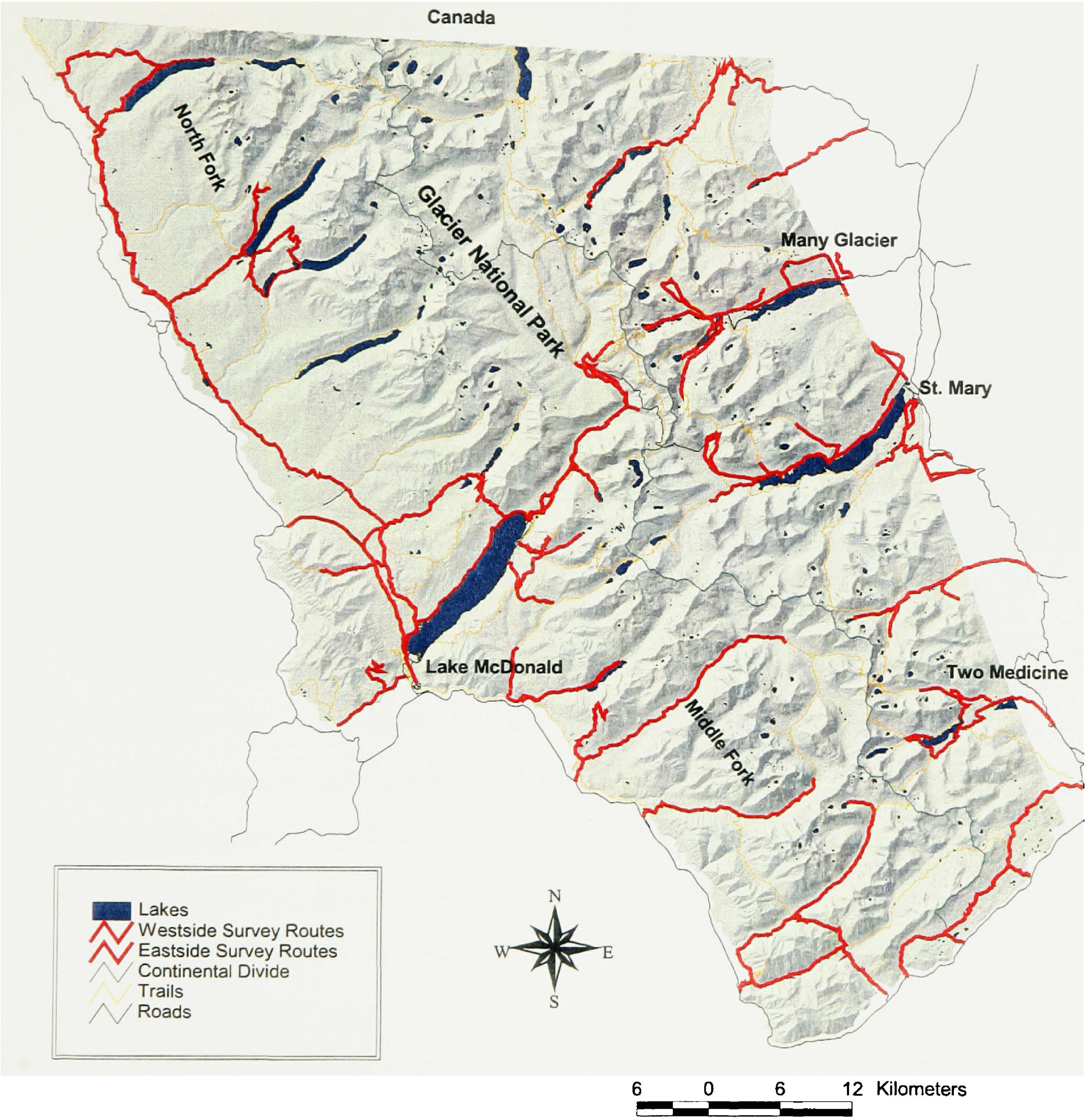

Figure 2. Track transects sampled during two winters of forest carnivore detection surveys in Glacier National Park, 1998-2000.

Species Detected

Twelve species of carnivores (lynx, fisher, wolverine, marten, mountain lion, grizzly bear, black bear, mink, river otter, striped skunk, coyote, and wolf) were detected during snow tracking (Table 1). The three smallest mustelids present in GNP (long-tailed weasel, short-tailed weasel, and least weasel) were not identified to species but were recorded as *Mustela* spp. when encountered along transects. Bobcat and red fox, carnivores common in areas just outside of GNP, were not detected during any of the surveys. Likewise, these two species were undetected in the 1994 pilot survey (Yates unpubl. 1994). Although bobcats and red foxes are occasionally observed at lower elevations in border regions of the park in summer, sightings of these species in winter are extremely rare (GNP files). Others animals detected along transects included: snowshoe hare, red squirrel, deer (*Odocoileus* spp.), elk, bighorn sheep, mountain goat, moose, grouse (*Dendragapus* spp.), muskrat, beaver, and several species of microtine rodents. One animal conspicuously absent from the list of species detected was the porcupine, considered "moderately common throughout the park" in the early 20th century (Bailey and Bailey 1918).

Table 1. Selected wildlife species detected along track survey routes (listed in alphabetical order), number of detections, kilometers traveled per detection, and hours surveyed per detection; Glacier National Park, two winters, 1998-2000.

Species	# of detections	Km / detection	Hours/ detection
Beaver (*Castor canadensis*)	5	305.0	146.2
Black bear (*Ursus americanus*)	1	1525.1	731.2
Coyote (*Canis latrans*)	200	7.6	3.7
Fisher (*Martes pennanti*)	67	22.7	10.9
Grizzly bear (*Ursus arctos*)	5	305.0	146.2
Lynx (*Lynx canadensis*)	82	18.6	8.9
Marten (*Martes americana*)	954	1.6	0.8
Mink (*Mustela vison*)	8	190.6	91.4
Moose (*Alces alces*)	172	8.9	4.3
Mountain lion (*Felix concolor*)	64	23.8	11.4
Muskrat (*Ondatra zibethicus*)	1	1525.1	731.2
Mustela spp.	894	1.7	0.8
River otter (*Lutra canadensis*)	8	190.6	91.4
Striped skunk (*Mephitis mephitis*)	1	1525.1	731.2
Wolf (*Canis lupus*)	53	28.8	13.8
Wolverine (*Gulo gulo*)	74	20.6	9.9

Lynx

Distribution

Lynx tracks were uncommon along routes on the west side of the Continental Divide (n=9), and relatively more common along routes on the east side (n=73) (Figure 3). Track detection rates for lynx were 97.3 km/detection on the west side and 8.9 km/detection on the east side. Lynx tracks were found at an average elevation of 1631 m (range, 1463 - 1945m) on the east side and 1168m (range, 1024m-1676m) on the west side. On the west side, lynx were detected in only two areas during both winters: the McDonald Valley and the southeast corner of the MFFR drainage near the Continental Divide. Two lynx detections occurred in the northern portion of the NFFR drainage during the winter of

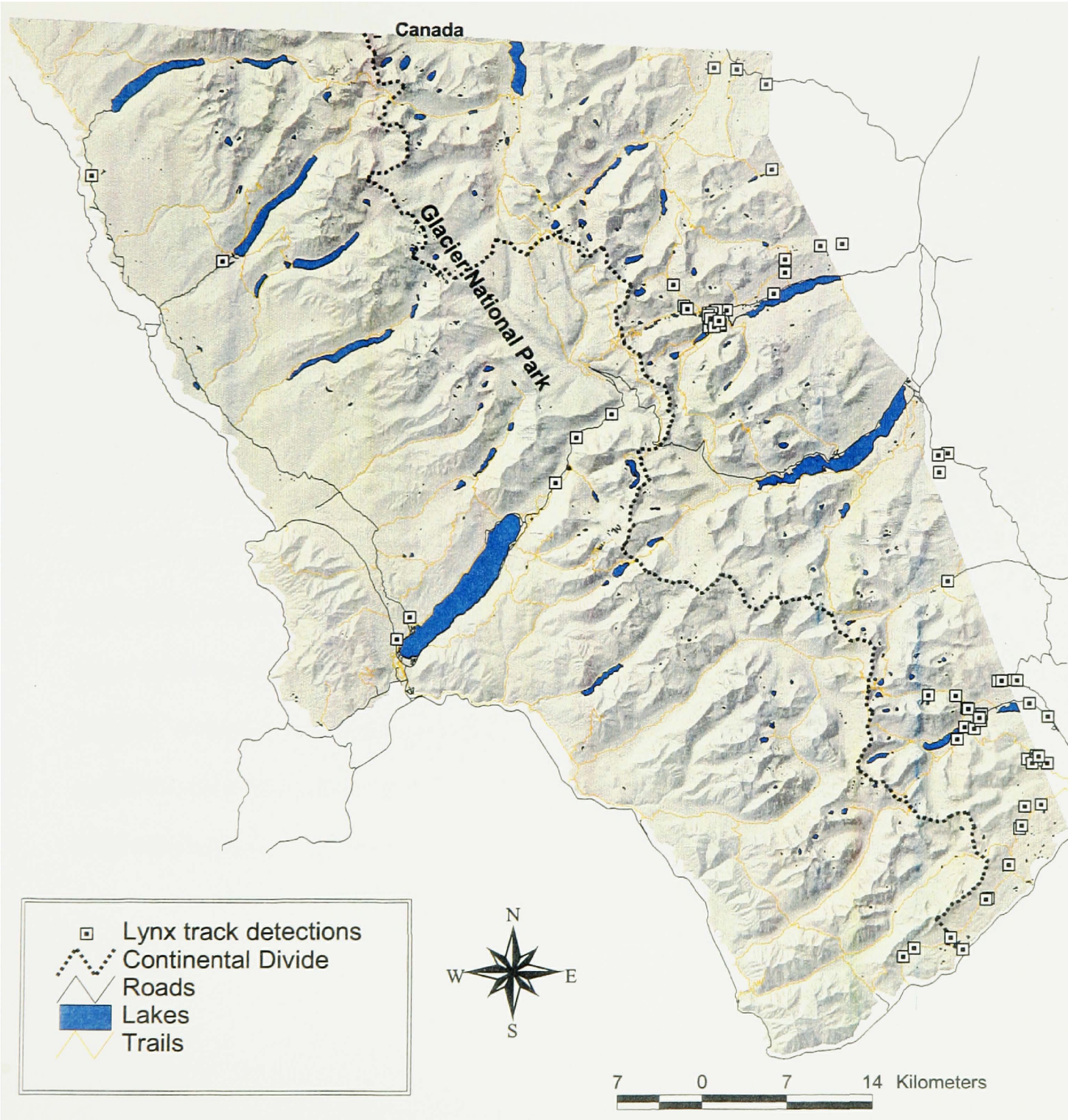

Figure 3. Distribution of lynx tracks (n=82) documented during two winters of forest carnivore detection surveys in Glacier National Park, 1998-2000.

1999/2000 only. On the east side of the study area, lynx appear to be well-distributed with documented occurrences from the Canadian border to the southeast boundary. Lynx were consistently detected in the Many Glacier and the Two Medicine areas during both winters. Lynx detections were notably absent in the upper St. Mary Valley where historical lynx occurrence has been documented (Barash 1971).

Habitat Use

Lynx were detected on slopes between 0 and 25 degrees (Table 2). Mean slope for east side and west side detections was similar (9 and 11 degrees respectively). Tracks were located on all aspects (Table 3). Most lynx detections occurred in areas where the understory density was relatively moderate (Table 4). Open stands were also used often.

Lynx detections were of one to four individuals (mean group size = 1.4 ± 1 (SD)). Tracks of family groups were observed in both the Many Glacier and Two Medicine drainages (both on the east side). No family groups were documented on the west side of the Continental Divide.

Table 2. Mean slope (in degrees) of lynx, fisher, and wolverine detections for the east and west sides of Glacier National Park, summary for two winters 1998-2000. Available slope was as follows: 24% (0-15 degrees), 42% (16-30 degrees), 30% (30-50 degrees), 6% (50+ degrees).

	Mean slope ± SD (range)	
	East Side	**West Side**
Lynx	9 ± 7.1 (range, 0-25)	11 ± 8.9 (range, 3-32)
Fisher	10 ± 8.3 (range, 2-32)	11 ± 10.0 (range, 0-40)
Wolverine	10 ± 10.2 (range, 0-37)	13 ± 9.8 (range, 1-38)

Table 3. Aspects of all lynx, fisher, and wolverine track detections by percentages. Summary of data from two winters of detection surveys, Glacier National Park, 1998-2000.

	% occurrence		
Aspect	**Lynx**	**Fisher**	**Wolverine**
Flat	15.8	26.9	21.5
N	7.3	1.5	4.1
S	18.3	14.9	16.2
E	11.0	3.0	5.4
W	6.1	8.9	5.4
NE	9.7	4.5	4.1
NW	9.7	17.9	17.6
SE	17.1	20.3	20.3
SW	4.9	8.9	5.4

Table 4. Relative understory density of all lynx, fisher, and wolverine track detections by percentages. Summary of data from two winters of detection surveys, Glacier National Park, 1998-2000.

	% occurrence		
Relative density	**Lynx**	**Fisher**	**Wolverine**
Open	32.9	29.8	33.8
Moderate	53.6	49.3	60.8
Dense	13.4	20.9	5.4

Lynx were detected in the following cover types: herb/shrub dry; herb/shrub mesic; deciduous tree/shrub; conifer forest, dense, moist; water; and conifer forest/dry. Over 96% of the detections occurred in the three forest cover types (Table 5). Comparison of habitat use to availability suggested that lynx did not select cover types at random ($P < 0.01$, $x^2 = 31.2$, df = 5) (Table 6). Mesic coniferous forest types constituted 43% of the cover types sampled by transects, but only 26% of lynx detections occurred in this type. The deciduous tree/shrub cover type constituted 12% of available habitat, yet 22% of lynx detections occurred in this type. Xeric coniferous forests constituted 31% of cover types sampled, but 49% of lynx detections occurred in this type. Lynx were detected in deciduous tree/shrub and dry coniferous forests more than expected and were detected in herb/shrub dry and conifer forest dense/moist significantly less than expected (Table 6).

Table 5. Cover types of all lynx, fisher, and wolverine track detections by percentages. Summary of data from two winters of detection surveys, Glacier National Park, 1998-2000.

Cover Type	% occurrence Available	Lynx	Fisher	Wolverine
1 (herb/shrub dry)	6.0	1.2	0.0	12.2
2 (herb/shrub mesic)	6.0	3.6	0.0	6.8
3 (deciduous tree/shrub)	12.0	22.0	19.4	20.2
4 (conifer forest, dense, moist)	43.0	25.6	43.3	31.1
5 (water)	0.1	2.4	0.0	1.3
6 (barren)	2.0	0.0	0.0	5.4
9 (conifer forest/dry)	31.0	48.8	37.3	23.0

Table 6. Chi-square analyses of total detections for lynx, fisher, and wolverine among 6 cover types in Glacier National Park, two winters, 1998-2000 ($x^2 = 11.07$, $P = 0.05$, df = 5) and ($x^2 = 15.09$, $P = 0.01$, df = 5). Observed detections are shown for each species in each cover type. Two asterisks indicate that the observed abundance was significantly greater than expected, whereas one asterisk indicates that the observed abundance was significantly less than expected.

Species	Cover Types 1 (herb/ shrub dry)	2 (herb/ shrub mesic)	3 (decid. tree/ shrub)	4 (conifer, moist)	6 (barren)	9 (conifer, dry)	X^2
Lynx (*Lynx canadensis*)	0*	1	18**	21*	0	40**	31.2
Fisher (*Martes pennanti*)	0*	0*	13**	29	0	25**	12.9
Wolverine (*Gulo gulo*)	9**	5	15**	23*	4	17*	16.6

Lynx were detected in stands ranging in age from 64 to 480+ years (Table 7). Random use of the six stand age classes was tested for the 79 lynx detections that occurred in a forest cover type. Comparison of habitat use to availability suggested that lynx use of multi and single stand age classes was not significantly different than expected by chance ($P > 0.05$, $x^2 = 10.7$, df = 5). When stands were classified into three categories (i.e. young, middle, old) and not differentiated by single or multiple age classes, lynx use of stand ages was significantly different than expected ($P < 0.01$, $x^2 = 9.3$, df = 2) (Table 8). Lynx use of old stands (pre 1844), was significantly higher than expected given the available habitat along transects. Approximately 64% of lynx detections in a forest cover type occurred in old forests (pre 1844). Lynx use of young and intermediate age classes was significantly lower than expected by chance.

Table 7. Stand age of all lynx, fisher, and wolverine track detections that occurred in forest habitats by percentages. For analysis, multi age stands were classified according to the age of the dominant stand component only. Summary of data from two winters of detection surveys, Glacier National Park, 1998-2000.

	% occurrence			
Stand Age	**Available**	**Lynx (n=79)**	**Fisher (n=67)**	**Wolverine (n=55)**
Single age - Young (post 1910)	15.0	10.0	7.0	15.0
Single age - Middle (1844 – 1910)	29.0	20.0	25.0	27.0
Single age - Old (pre 1844)	17.0	27.0	19.5	22.0
Multi age - Young (post 1910)	4.0	2.0	1.5	4.0
Multi age - Middle (1844 – 1910)	7.0	6.0	4.5	7.0
Multi age - Old (pre 1844)	28.0	35.0	42.0	25.0

Table 8. Chi-square analyses of total detections for lynx, fisher, and wolverine among 3 stand ages in Glacier National Park, two winters, 1998-2000 (x^2= 5.99, P =0.05, df = 2). Observed detections are shown for each species in each stand age category. Two asterisks indicate that the observed abundance was significantly greater than expected, whereas one asterisk indicates that the observed abundance was significantly less than expected.

Species	**Stand Ages**			
	Young (post 1910)	**Middle (1844-1910)**	**Old (pre 1844)**	X^a
Lynx (*Lynx canadensis*)	9*	37*	49**	9.3
Fisher (*Martes pennanti*)	6*	20	41**	8.4
Wolverine (*Gulo gulo*)	10	19	26	0.1

Fisher

Distribution

Fisher detections were relatively more common along routes on the east side of the Continental Divide (20 km/detection), than on the west side (25 km/detection) (Figure 4). Fisher tracks were found at an average elevation of 1550 m (range, 1390 m – 1798 m) on the east side and 1152 m (970 – 1585 m) on the west side. Of the 35 west side detections, 28 occurred in the upper McDonald Valley and lower NFFR Valley, suggesting a possible fisher stronghold in this area. A scattering of fisher detections (n=7) occurred in the upper NFFR Valley and in 2 areas of the

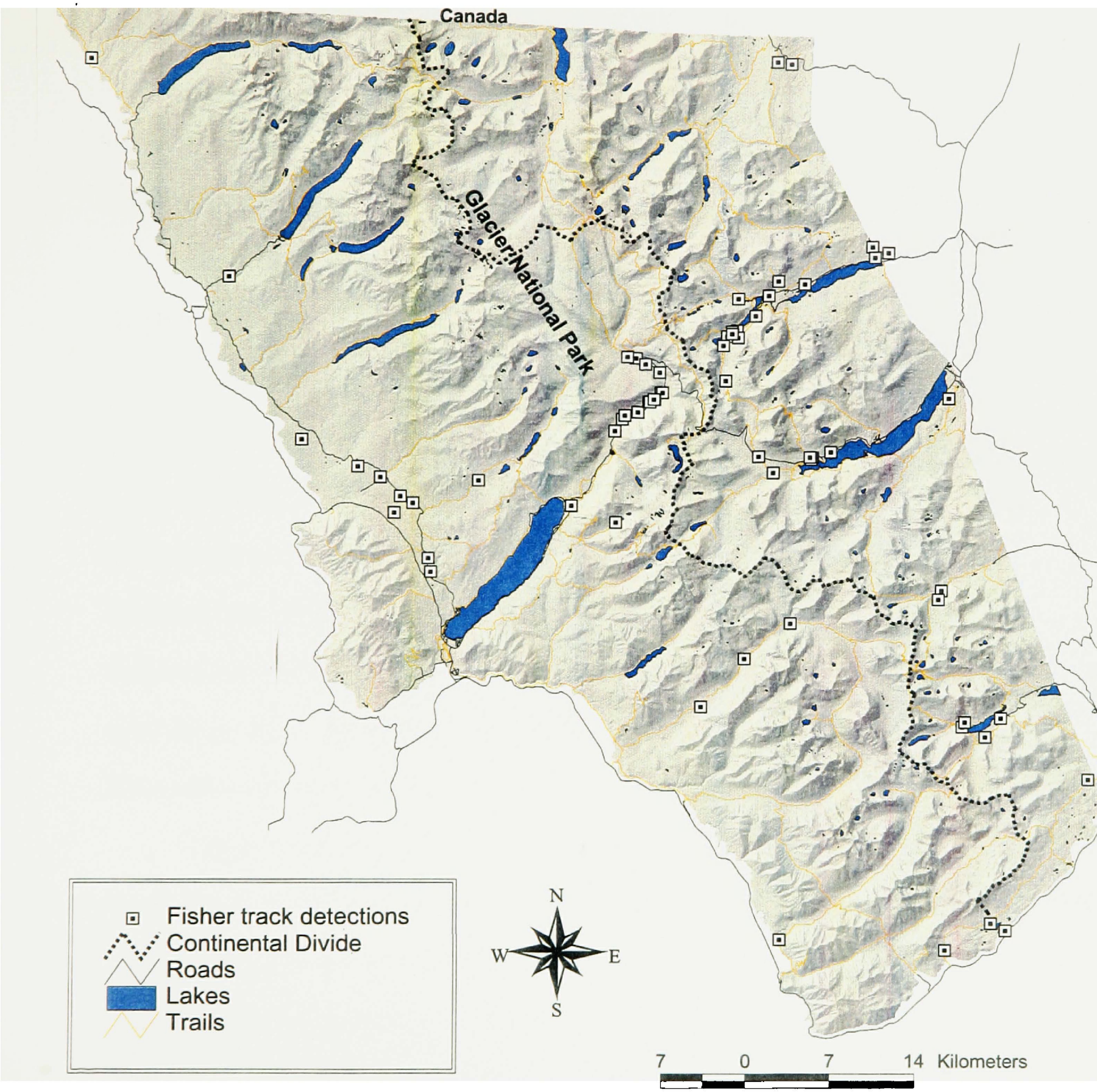

Figure 4. Distribution of fisher tracks (n=67) documented during two winters of forest carnivore detection surveys in Glacier National Park, 1998-2000.

MFFR Valley. Along the eastern slopes of the study area, fisher detections were well distributed. Several detections occurred along/outside of the GNP boundary suggesting that suitable fisher habitat likely occurs on the Blackfeet Indian Reservation as well.

Habitat Use

Fishers were detected on slopes between 0 and 40 degrees (Table 2). Mean slope for east side and west side detections was similar (10 and 11 degrees respectively). Tracks were located on all aspects (Table 3). Most fisher detections occurred in areas where the understory density was relatively moderate (Table 4). Dense and open stands were also used. Detections were of 1 to 2 individuals (mean group size = 1.0 ± 0.2 (SD)). Tracks of two fishers travelling together were observed on 3 occasions, twice in the McDonald Valley (west side) and once in the Many Glacier area (east side). Detections of multiple animals were made in November, December, and March respectively.

Fishers were detected in the following cover types: deciduous tree/shrub; conifer forest, dense, moist; and conifer forest/dry. Fishers were never detected in shrub fields or grassland habitats (Table 5). Random use of the seven cover types was tested for the 67 fisher detections. Comparison of habitat use to availability suggested that fisher did not select cover types at random ($P < 0.05$, $x^2 = 12.9$, df = 5) (Table 6). One hundred percent of the detections occurred in the three forest cover types. Fishers used the mesic forest type according to availability. The deciduous tree/shrub and conifer forest/dry cover types were used significantly more than expected.

Fishers were detected in stands ranging in age from 33 to 480+ years (Table 7). Random use of the six stand age classes was tested for the 67 fisher detections that occurred in a forest cover type. Comparison of habitat use to availability suggested that fisher use of multi and single stand age classes was not significantly different than expected by chance ($P > 0.05$, $x^2 = 5.7$, df = 5). When stands were classified into three categories (i.e. young, middle, old) and not differentiated into single or multiple age classes, fisher use of stand ages was not random ($P < 0.05$, $x^2 = 8.4$, df = 2) (Table 8). Fisher use of old stands (pre 1844) was significantly greater than expected. Forty two percent of fisher detections occurred in multi age old forests where structural diversity is probably high.

Wolverine

Distribution

Wolverine tracks were detected 74 times in the two winters between 1998 and 2000. Despite the fact that 34% more effort was spent surveying transects on the west side of the Continental Divide, more wolverine detections were made on the east side of the study area (n=53) than on the west side (n=21) (Figure 5). Wolverine tracks were found at an average elevation of 1622 m (range, 1457 – 2341 m) on the east side and 1279 m (range, 1003 – 2109 m) on the west side. Approximately

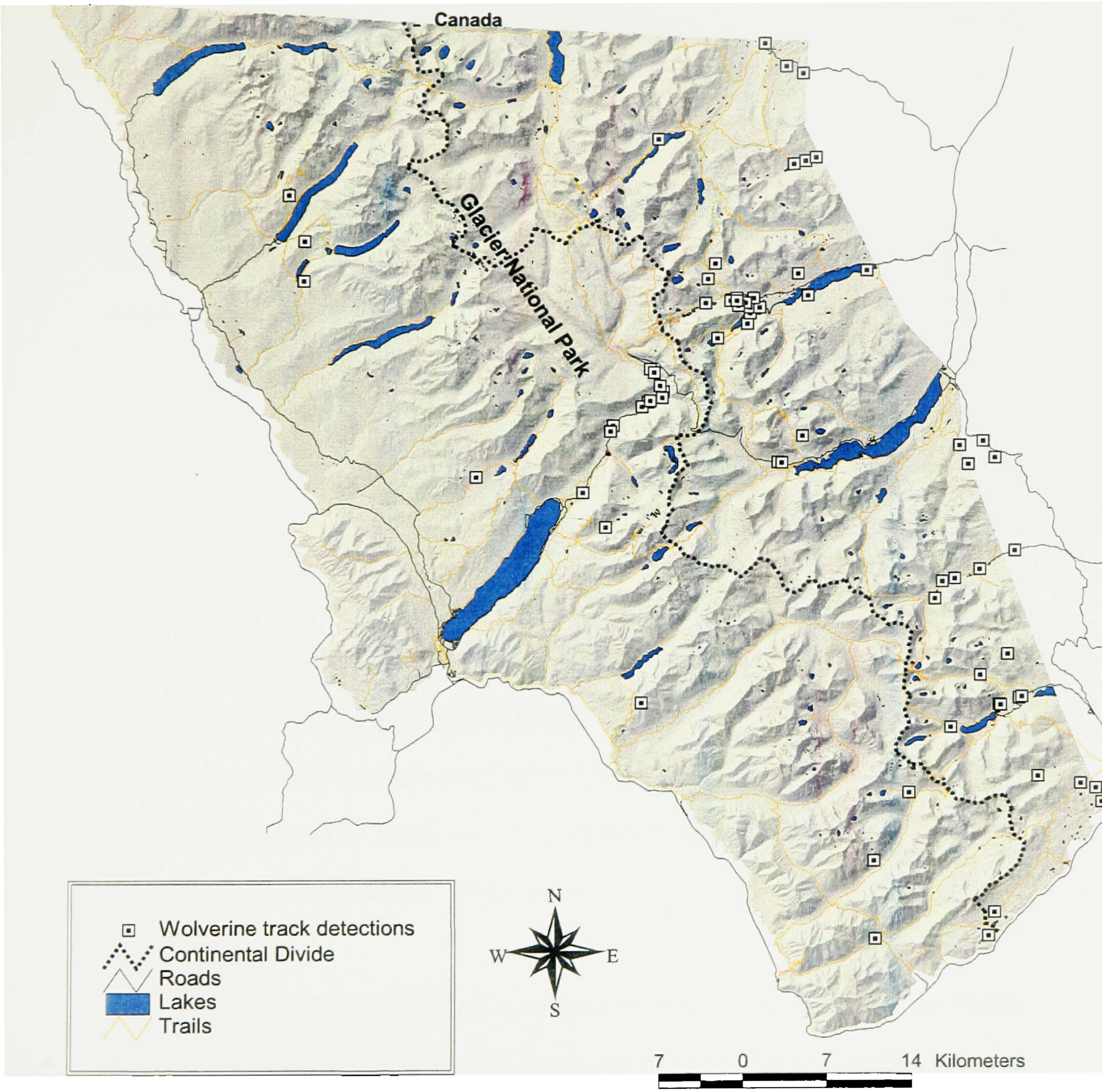

Figure 5. Distribution of wolverine tracks (n=74) documented during two winters of forest carnivore detection surveys in Glacier National Park, 1998-2000.

half of the west side wolverine detections occurred in the McDonald Valley, while the other 10 detections occurred in 3 drainages of the NFFR and 5 drainages of the MFFR. Wolverine detections on the east side were well distributed from north to south in nearly every major drainage. Wolverine were detected outside of GNP on the Blackfeet Indian Reservation on several occassions. Snow tracking indicated that wolverines on the east side of GNP moved freely across the park boundary and were often located near ungulate winter ranges. Wolverine were frequently located at the lowest elevations on the east side and often in/or adjacent to developed areas (hotels, campgrounds, and ranger stations that receive little to no human use in winter months). In general, wolverines detected on the west side of the study area, were not detected at the lowest elevations where deer and elk winter ranges occur. Most west side wolverine detections occurred several kilometers up side drainages and well within the park boundary. Lower elevation areas along GNP's western boundary were extensively surveyed yet no wolverine were detected in these areas.

Habitat Use

Wolverine were detected on slopes between 0 and 38 degrees (Table 2). Mean slope for east side and west side detections was similar (10 and 13 degrees respectively). Tracks were located on all aspects (Table 3). Most wolverine detections occurred in areas where the understory density was moderate to open (Table 4). Only 5.4% of wolverine detections occurred in areas with a relatively dense understory. Detections were of 1 to 2 individuals (mean group size = 1.0 ± 0.0 (SD)). Tracks of two wolverine travelling together were observed on 2 occasions, once in the Otatso Creek drainage and once in the Many Glacier area (both east side). These observations occurred in late January and mid-March respectively. No natal or maternal dens were detected.

Wolverines were detected in the following cover types: herb/shrub dry, herb/shrub mesic, deciduous tree/shrub, conifer forest, dense, moist, water, barren, and conifer forest/dry (Table 5). Random use of the seven cover types was tested for the 74 wolverine detections. Comparison of habitat use to availability suggested that wolverine did not select cover types at random ($P < 0.01$, $x^2 = 16.6$, df = 5) (Table 6). Seventy four percent of the detections occurred in the three forest cover types. These three forest types constituted 86% of the cover types sampled by transects. Twenty–six percent of the wolverine detections occurred in cover types that lacked significant canopy cover (shrub fields, grassland, talus fields, and frozen lakes). The deciduous tree/shrub and herb/shrub dry cover types were used significantly more than expected by availability. Both conifer forest cover types were used significantly less than expected (Figure 6).

When wolverine were detected in forested habitats, stand ages ranged from from 33 to 480+ years (Table 7). Random use of the six stand age classes was tested for the 55 wolverine detections that occurred in a forest cover type. Comparison of habitat use to availability suggested that wolverine use of multi and single stand age classes was not significantly different than expected by chance ($P > 0.05$, $x^2 = 0.5$, df = 5). When stands were classified into three categories (i.e. young, middle, old) and not differentiated by single or multiple age classes, wolverine use of stand ages was again not significantly different than expected ($P > 0.05$, $x^2 = 0.1$, df =2) (Table 8). Although 47% of wolverine detections in a forest cover type occurred in old stands (pre 1844), this figure was not significantly different than expected given the available habitat along transects.

Marten

Distribution

Marten tracks were observed in all three of the forest cover types described for the study area. The distribution of forest cover types in the study area is represented in Figure 6. Although the UTM locations for every marten track encountered (n=954) were not recorded during the surveys, marten winter distribution was mapped according to presence/absence data collected along transects (Figure 7). Marten were detected along 68 of the 73 transects surveyed. Of the five transects where marten were not detected, four were only sampled once. It is possible that marten have not been detected along the Many Glacier Road because snow conditions along this route are usually poor for tracking (due to wind) and there is relatively little forest cover. The other

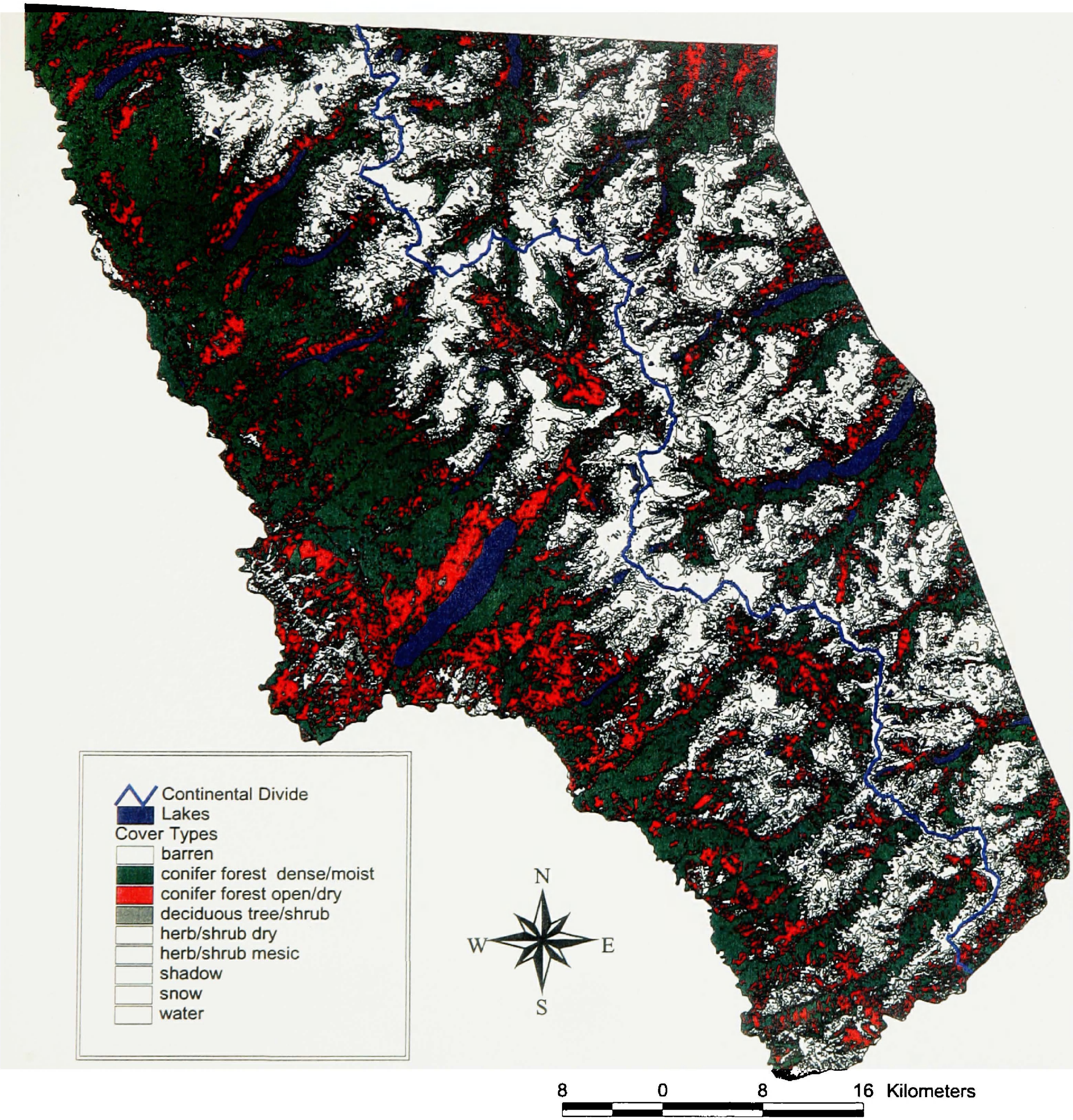

Figure 6. Distribution of forest cover types in Glacier National Park.

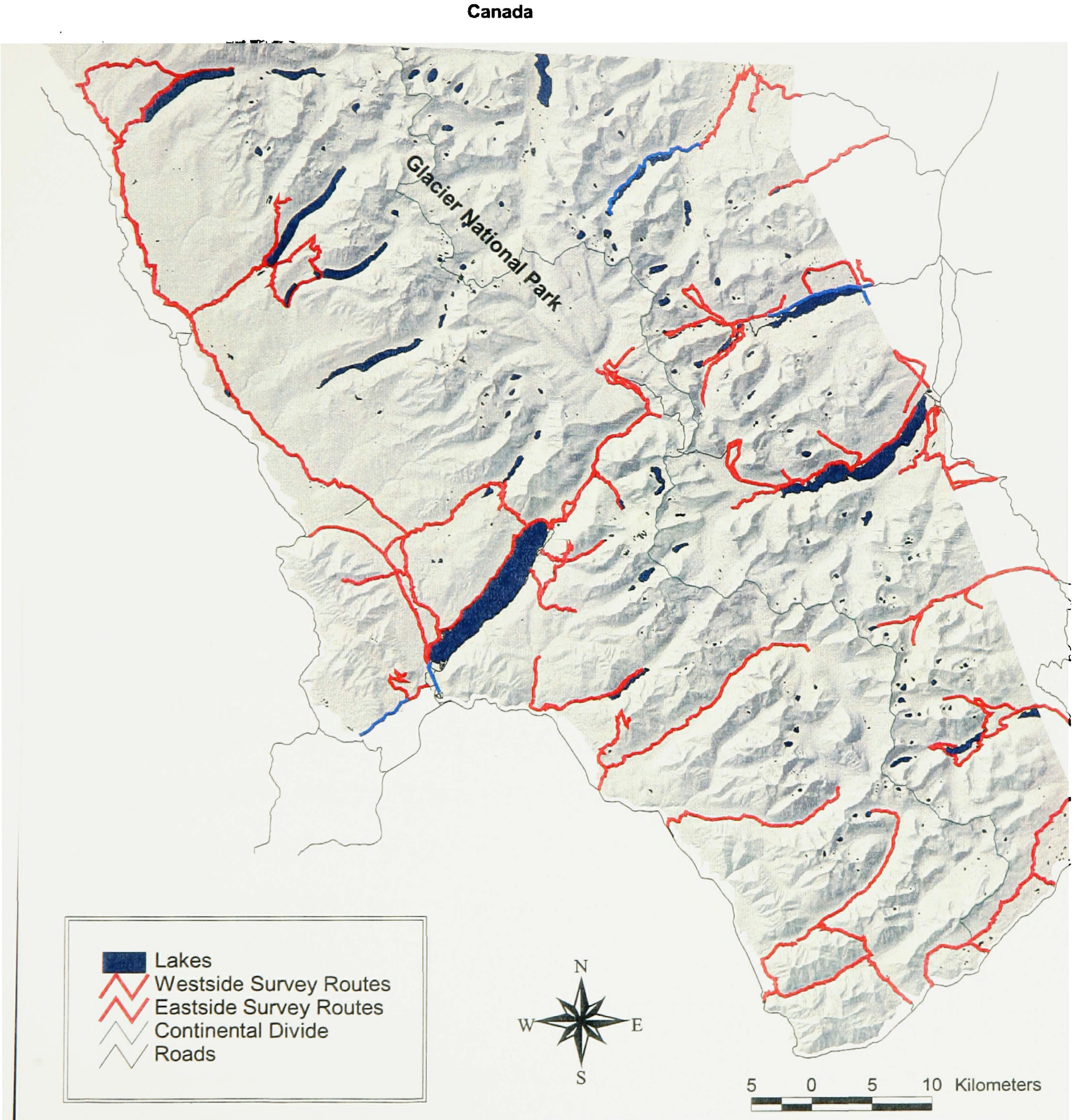

Figure 7. Transects along which marten tracks were observed during two winters of snow track surveys in Glacier National Park, 1998-2000. Martens were detected along routes marked in red but were not detected along routes marked in turquoise.

four transects appear to traverse suitable marten habitat and are proximate to routes where marten have been detected. Marten appear to have a wide distribution in GNP and occur across the elevational gradient sampled by the transects. Detection rates for the east side and the west side were similar: 1.7 km/detection (west side) and 1.4 km/detection (east side). Since exact locations were not recorded for each set of marten tracks encountered, an analysis of marten habitat use at the stand level could not be conducted using the data collected.

Coyotes

Although the UTM locations for every coyote track encountered (n=200) were not recorded during the surveys, coyote presence/absence and track counts were noted for each transect segment. The mean elevation for coyote tracks east of the Continental Divide was 1530 m (range, 1372 – 2011 m). Coyote tracks were detected during 54 of 81 surveys (67%). Eighty-nine percent of coyote detections on the east side occurred on closed roads with little snow cover or within 3 km of the trail head (where plowed road access terminated). Only 11% of coyote detections on the east side occurred in the backcountry (more than 3 km from a trailhead). Several of the backcountry detections were made in March, a month when snow conditions are the most variable due to temperature fluctuations.

Coyote tracks were detected during 27 of 94 surveys on the west side or (29%). Mean elevation for coyote detections on the west side was

1165 m (range, 945 – 1737 m). The mean distance to trailhead for coyote detections on the west side was 4.7 km (range, 0.1 - 15.0 km). Of the coyotes detected on the west side, 45% occurred within 3 km of a trailhead, 50% were within 3 km of ungulate winter range, and 5% were located outside of these two areas. Therefore, 95% of coyote detections on the west side occurred within 3 km of a trailhead (where plowed road access terminated) or ungulate winter range (where snow depths are lowest). On both the east and west sides of the study area, coyotes were detected most often at lower elevations and in/or near areas of low snow accumulation or snow compaction from human use (Table 9).

Table 9. Mean elevation of lynx, fisher, wolverine, coyote, and mountain lion detections for the east and west sides of Glacier National Park, summary for two winters 1998-2000.

	Mean elevation (range)	
	East Side	**West Side**
Lynx	1631 m (1463 – 1945 m)	1168 m (1024 – 1676 m)
Fisher	1550 m (1390 – 1798 m)	1152 m (970 – 1585 m)
Wolverine	1622 m (1457 – 2341 m)	1279 m (1003 – 2109 m)
Mountain lion	1501 m (1371 – 1676 m)	1132 m (914 – 1524 m)
Coyote	1530 m (1372 – 2011 m)	1165 m (945 – 1737 m)

Mountain Lions

Tracks of mountain lions were detected at 64 locations in the study area (22 detections on the east side and 42 on the west side). Mean elevation for mountain lion detections on the east side was 1501 m (range, 1371 – 1676 m). Seventy-seven percent of the east side detections occurred on closed roads or within 3 km of a trailhead (where plowed road access terminated). Of the 23% of the detections that occurred in the backcountry (n=5), 100% occurred between 11 March and 21 March, when the snow pack is often crusty/compacted due to daily freezing and thawing. Mountain lions were detected during 18% of east side surveys.

Of the 42 west side mountain lion detections, 98% (n=41) occurred within 3 km of a trailhead or ungulate winter range (where snow depths were lowest). Mean elevation for mountain lion detections on the west side was 1132 m (range, 914 – 1524 m). One detection of a mountain lion occurred in the backcountry (more than 3 km from a trailhead or ungulate winter range). On 11 March 2000, two mountain lions (female with a kitten) traveled from the head of Lake McDonald white-tailed deer winter range (where the same pair had been detected in December, January, and February) up and over Howe Ridge (1524 m) and down into the Camas Creek drainage. It is the only time on the west side that mountain lions were detected above 1250 m and greater than 3 km from a trailhead or ungulate winter range. Mountain lions were detected during 31% of west side surveys.

Carnivore Summary

Mean elevations of lynx, fisher, wolverine, coyote, and mountain lion detections are presented in Table 9. On the east side of the study area, it appears that lynx and wolverine occupy the highest elevations (sampled by our transects) followed by fisher, coyote, and mountain lion respectively. On the west side, wolverine appear to occupy the highest elevations of the five carnivores described here, with lynx and fisher next, followed by coyotes and mountain lions. Although lynx, fisher, and wolverine occur at different mean elevations in the study area, there is overlap in the range of elevations at which these three species occur (Figure 8). Coyotes and mountain lions appear to occupy the lowest elevations in the study area and occur at higher elevations only rarely and usually in early spring (March).

Prey Species

Tracks of snowshoe hare, red squirrel, grouse and microtine rodents were tallied along each survey route (Appendices C-F). Track counts for snowshoe hare were higher along transects on the east side of the study area during both winters. Squirrel tracks were higher on the west side in 1998/1999 but lower in 1999/2000. Squirrel and hare tracks were relatively common in the areas sampled. These species were regularly detected along transects throughout the study area, while grouse and microtines were less common.

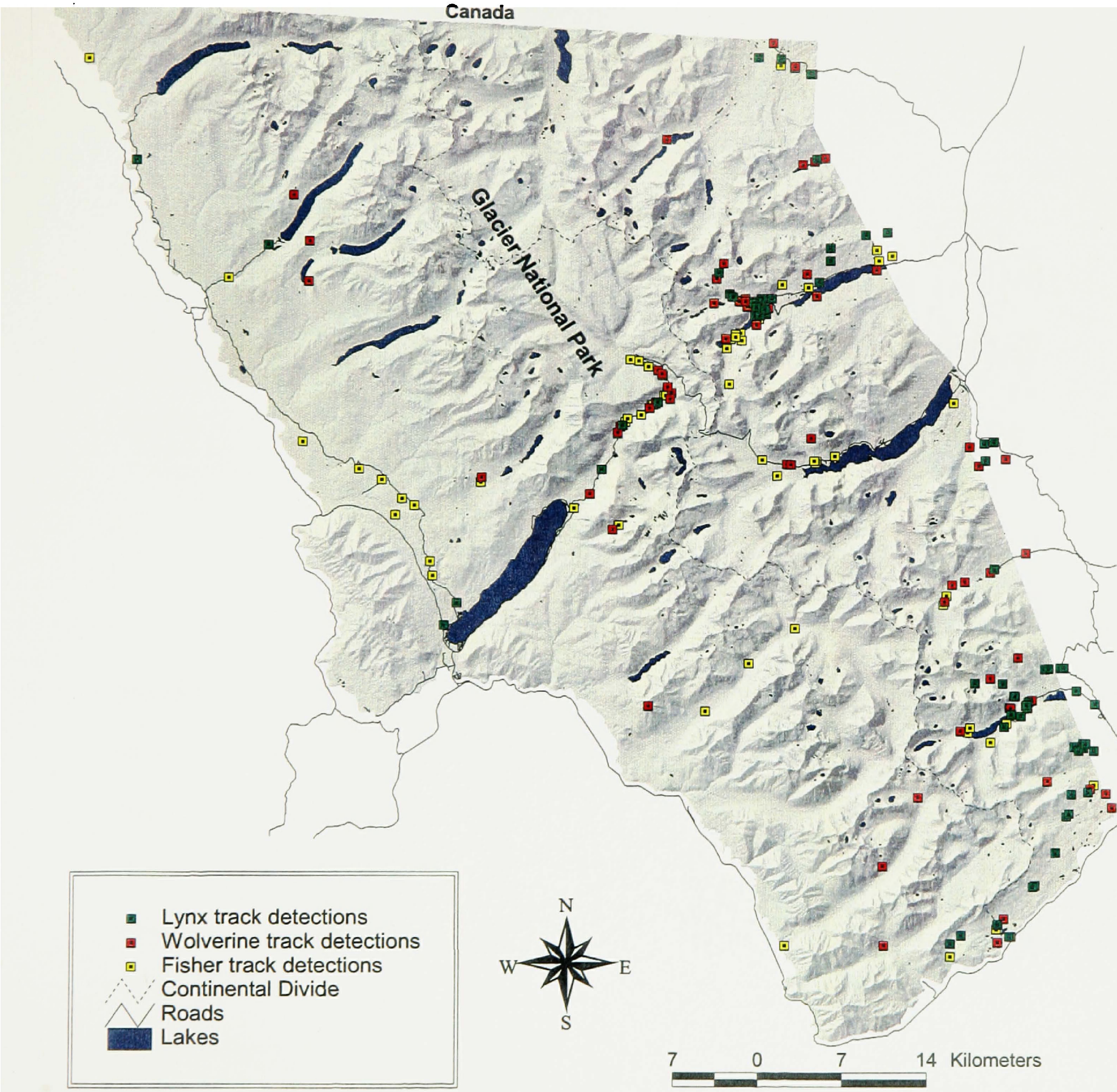

Figure 8. Distribution of lynx, fisher, and wolverine tracks documented during two winters of forest carnivore detection surveys in Glacier National Park, 1998-2000.

Table 10. Mean number of prey tracks detected per kilometer by geographic region and year, Glacier National Park, two winters 1998-2000. The mean was calculated for routes that were surveyed more than once, and the range of values appears in parenthesis.

	Mean number tracks/kilometer (range)			
	Snowshoe hare	**Red squirrel**	**Grouse *Dendragapus* spp.**	**Microtine rodents**
1998/1999				
West Side	1.75 (0.3 – 4.8)	2.40 (0.2 – 8.9)	0.30 (0.0 – 1.0)	0.57 (0.0 – 3.6)
East Side	2.16 (0.1- 10.2)	1.20 (0.0– 12.8)	0.27 (0.0 – 2.3)	0.06 (0.0 – 0.5)
1999/2000				
West Side	1.00 (0.1 - 4.0)	0.97 (0.1 – 9.2)	0.29 (0.0 – 1.1)	0.05 (0.0 – 0.5)
East Side	5.20 (0.3 -14.6)	1.40 (0.0 – 5.1)	0.30 (0.0 – 0.4)	0.60 (0.0 – 5.1)

Ungulates

Elk, bighorn sheep, mule deer, white-tail deer, and mountain goats are not included in Table 1 because tracks of these five species were not tallied during the surveys. On the west side of GNP, deer tracks were detected during 56 of 94 surveys (59%) conducted and elk tracks were detected during 30 surveys (32%). Tracks of bighorn sheep were detected during one survey on the west side (1%). On the east side of GNP, elk tracks were detected during 20 of 81 surveys (25%) conducted; deer tracks were detected during 22 surveys (27%); and one survey detected tracks of bighorn sheep and mountain goats (1%). Moose detections were summarized in Table 1.

Remote-sensing Cameras

The two Trail Master remote-sensing camera systems were deployed for over 100 traps nights at several locations each field season. All sites were located near trails and within one day of foot travel from a trailhead. In general, the cameras functioned well considering the duration of use and the cold temperatures common in the study area, especially east of the Continental Divide. On one occasion, a small mammal chewed through the cable connecting the camera to the sensor disengaging the system. Covering the cable with duct tape or swiping it with rubbing alcohol to remove salts and human scent appeared to solve this problem. In general, 14 days was the maximum amount of time the cameras would operate before the batteries and film needed replacing. When temperatures were extremely low, the batteries seemed to last about 7 days. Photographs of a golden eagle, marten, and fisher (probable) were obtained at a station that was located at a bighorn sheep carcass. Photos of mountain lion, wolverine, bighorn sheep, snowshoe hare, and gray jays were obtained at a station in the Many Glacier Valley. Two photographs of lynx were also obtained at this site. One photo was of a large adult lynx (possibly a male), and the other photo was of a lynx family group (one adult and one kitten).

DISCUSSION

Lynx

In Montana, lynx have been intensively studied using radio-telemetry in four areas: the South Fork of the Flathead (Koehler et al. 1979), Garnet Mountains (Smith 1984), Cabinet Mountains (Brainerd 1985), and the Seeley-Swan Valley (Squires and Laurion 2000). Studies of lynx in northeast Washington (Koehler 1990, Brittell et al. 1989, McKelvey et al. 2000b) and the Canadian Rockies (Apps 2000), may be applicable to Montana as well. Koehler et al. (1979) found most lynx use in dense lodgepole pine stands approximately 50 – 60 years old. The remaining relocations were in stands dominated by subalpine fir/Engelmann spruce and mature Douglas-fir/western larch. Lynx in North Central Washington used areas with slopes <10% and showed little use of areas below 1400 m or above 2150 m (McKelvey et al. 2000a). The majority of lynx use in winter occurred in the lodgepole pine and subalpine fir classes (64%) (McKelvey et al. 2000b). A preference for northeast aspects was noted in summer only (possibly for thermoregulation) (McKelvey et al. 2000b). The 11 lynx radio-collared and tracked in the Cabinet and Garnet Mountains occurred mainly in subalpine fir forest associations (Smith 1984, Brainerd 1985).

In the Swan-Seeley Valley and the Canadian Rockies, lynx home ranges occurred at mid-elevations (1550 m – 1850 m) dominated by spruce-fir forests, with lodgepole pine as a seral species (Apps 2000, Squires and Laurion 2000). Lynx are reported to use mixed conifer and hardwood stands in Montana as well (J. Squires, pers. comm. 1999; cited in Ruediger et al. 2000). Lynx detected along track transects in GNP, like lynx in the Swan-Seeley Valley and the Canadian Rockies occurred both in mesic spruce-fir forests and in drier mixed conifer (Douglas-fir, limber pine, subalpine fir) and lodgepole pine stands. In fact, lynx detected in GNP occurred in dry conifer stands (mixed conifer and lodgepole pine) more often than in moist conifer stands, and relative use of these two categories was significantly different than expected.

Lynx detected along transects in GNP were rarely found below 1220 m, and most detections occurred at mid-elevations. The most prominent aspects were south, southeast, and flat (in order of use) suggesting a possible preference for the warmest, driest slopes. Most lynx occurrences occurred on gentle slopes, similar to findings elsewhere. Apps (2000) and Koehler (1990) found that many of the lynx they studied used mean elevations that were higher during summer than during winter. The summer 2000 GNP lynx detection survey detected lynx in areas on the east side where lynx were also detected in winter (Edmonds et al., unpubl. 2000). Whether individual lynx move to higher elevations in summer cannot be determined using these methods; however, it appears that several areas on the east side of the park provide year-round habitat for lynx. Lynx were detected in both summer and winter within 1 km of two developed areas that received heavy visitor use in summer but were difficult to access and rarely visited by humans in winter. Further investigation of the influence of habitat quality, behavioral diversity and type, seasonality and intensity on lynx distribution and habitat us is warranted.

McKelvey et al. (2000b) assessed the concordance between location data from road-based track and camera surveys and telemetry data for 22 lynx in North Central Washington and found that lynx detected along roads used different habitats than those predicted by telemetry data. As the road-based surveys did not provide a representative sample of the surrounding vegetative classes, the authors concluded that patterns of use appeared to have been influenced mostly by the composition of adjacent habitats (i.e., proximity to lodgepole pine stands). The roads tended to pass through Douglas-fir classes, while the landscape was dominated by lodgepole pine classes, making inferences about habitat use inadvisable (McKelvey et al. 2000b). The proportion of vegetative cover types sampled by track transects in GNP did not differ significantly from the proportion available in the study area, making it possible to describe habitat use patterns with some confidence. Although this study only examined lynx habitat use at the stand level, it raises several questions regarding lynx habitat at a variety of spatial scales. Future studies should investigate the distribution, abundance, and availability of lynx prey in forests where lynx are known to occur in GNP. The literature suggests that lynx are more influenced by the patchy distribution of snowshoe hares in winter than any other habitat component (McKelvey et al. 2000b). At the landscape scale, it would be valuable to examine the extent to which patterns and levels of interspersion affect habitat suitability for lynx.

The importance of aspen stands as a component of snowshoe hare and lynx habitat is not well understood. Wolfe et al. (1982) found that hares use aspen stands much less than conifer stands if they lack dense understory cover. Other authors speculate that aspen stands intermixed with spruce-fir or lodgepole pine stands, particularly those with dense regeneration or understory vegetation, may contribute substantially to prey productivity (Ruediger et al. 2000). Several researchers found snowshoe hare densities directly and positively correlated with densities of small diameter woody stems (Koehler and Aubry 1994). Stand structure appears to be more important in predicting snowshoe hare abundance than forest type or stand age (Mowat et al. 2000). Although early-successional habitats usually provide the structural complexity and horizontal cover preferred by snowshoe hares, late successional forests may contain these features as well. Buskirk et al. (2000) hypothesized that in mesic forests, "hare densities should be bimodal with stand age: highest in early seral conditions, minimal in closed-canopy mature forests, and reaching moderate densities in extremely old gap-phase forests." Most studies of snowshoe hare habitat use have been conducted in eastern North America, while data for snowshoe hares along entire successional trajectories in the West is scant (Buskirk et al.

2000). Thompson et al. (1989), Beauvais (1997), and Mills and Henderson (unpubl. data, cited in Buskirk et al. 2000b) found hares relatively abundant in late successional coniferous forests. Mature and older conifer forests are also preferred habitats of red squirrels, an important alternate prey of lynx in the West (Apps 2000). Buskirk et al. (2000b) recommended further research on the importance of structural habitat correlates and old gap-phase forests with regard to the habitat needs of snowshoe hares. The high variability in snowshoe hare track data for the east and west sides of GNP suggests that the east side of the park may presently contain the most productive habitat for hares and consequently for Canada lynx. GNP contains a relatively high proportion of old forests, especially on the east side where fire suppression has significantly altered historic fire cycles. Small scale disturbances in a matrix of older forests may provide the habitat features most suitable for lynx and their prey than the large-scale, stand replacing disturbances that now characterize much of the west side.

Lynx home ranges south of Canada are relatively large, and probably include denning, resting, and foraging habitats, as well as marginal habitats used primarily for travelling between hunting sites (Ruediger et al. 2000). Brittell et al. (1989) described suitable lynx travel cover as coniferous or deciduous vegetation > 2 m in height with a closed canopy that is adjacent to foraging habitats.

Lynx use of habitats along track transects in GNP indicated a preference for older forest age classes. Lynx use of preferred habitats for hunting or travel cannot be known from the methods used in this study. Lynx showed no preference for multi age stands as compared to single age stands. Multi age stands in the intermediate to mature range may exhibit more structural complexity than even aged stands, but this assumption has not been verified in the field. The chosen measure of horizontal cover in this study (i.e. relative understory density) proved too subjective for meaningful analysis. A better method would have been the quantification of stem density and understory height. Future research should investigate the structural characteristics and prey associations of late-successional mesic/dry conifer and deciduous forests in our study area. Little is known about the relative productivity of these habitats in the Rocky Mountains for lynx and snowshoe hares. A sampling design similar to methods used by Thompson et al. (1989) to measure the relative occurrence of hares and lynx in various cover types and stand age classes would better describe snowshoe hare habitat use than the methods employed in this study.

In the Rocky Mountains, a complex suite of predators that includes lynx, coyotes, bobcats, fishers, martens, red foxes, mountain lions, northern goshawks (*Accipiter gentilis*), and great horned owls compete for snowshoe hares in montane coniferous forests. Predation on lynx by mountain lions, bobcats, wolverines, and coyotes has been documented

(Ruediger et al. 2000). Interference and/or exploitation competition from coyotes, bobcats, and mountain lions may be significant factors influencing lynx distribution and population viability (Buskirk et al. 2000a). Due to their lower foot loading, lynx can exploit high elevation areas where deep snow probably excludes coyotes, bobcats, and mountain lions. Smith (1984) found that bobcat home ranges were at significantly lower elevations during winter than were lynx home ranges, but extensive spatial overlap was noted during snow-free periods. Murray and Boutin (1991) found coyotes to be more selective of hard or shallow snow conditions than were lynx. In the southern portions of lynx range, snow conditions may vary considerably in response to frequent winter thaws and subsequent crust formation. Crusted snow conditions could permit carnivores with higher foot loadings such as mountain lions, bobcats, and coyotes, to access higher elevation habitats in winter thereby negating the competitive advantage held by lynx (Buskirk et al. 2000).

Snow conditions in GNP may restrict movements of coyotes and mountain lions to lower elevation areas where snow depths are lowest. It is also possible that prey abundance influences the distribution of coyotes and mountain lions. Although bobcats are occasionally sighted in the park in summer, no tracks of bobcats were detected in over 1500 km of track transects in two winters. Potential interference competition from bobcats, coyotes, and mountain lions in winter appears to be low for lynx on the study area given the high degree of spatial separation observed. Coyotes and mountain lions were very rarely detected at higher elevations or in the backcountry. Most remote detections of coyotes and mountain lions occurred in March when snow conditions on the study area were highly variable due to regular freezing and thawing. GNP gets relatively little use by winter recreationists (notably absent are snowmobiles). Further research into the winter distribution and movement patterns of lynx in relation to coyotes and mountain lions in GNP could be extremely informative. GNP may serve as an important refugia for lynx in the western U.S. especially in winter when natural conditions predominate and access for recreationists is poor.

Fisher

Only three intensive, radio-telemetry-based studies of fisher ecology and habitat use have been conducted in the Rocky Mountains (Heinemeyer 1993; Jones 1991; Roy 1991), and two of those studies were of reintroduced populations from Wisconsin and Minnesota (Heinemeyer 1993 and Roy 1991). Inferences from studies on introduced populations to extant populations elsewhere in the Rocky Mountains may be limited. Fishers in all three of these studies selected riparian areas with relatively gentle slopes and dense canopy cover.

In Idaho, Jones (1991) found that fishers preferred late-successional coniferous forests with complex physical structure, especially in summer. Fishers in Idaho also avoided nonforested areas such as forest openings, open hardwood forests, recent clearcuts, grasslands, and areas above timberline (Jones 1991). Jones (1991) and Roy (1991) both found that fishers preferred young to medium age stands of conifers at certain times of the year. Jones (1991) and several other researchers have found that fishers use most forest types within extensive northern-conifer forests (Powell and Zielinski 1994). Buskirk and Powell (1994) stated that forest type is probably less important to fishers than aspects of forest structure related to prey abundance and denning/resting sites. Some authors have hypothesized that where snow is deep and frequent (such as GNP), fishers should be expected to be absent or occur where dense overhead cover intercepts snowfall (Powell and Zielinski 1994).

Fishers detected along transects in GNP occurred in old forests significantly more than expected by chance which is similar to the findings of Jones (1991) and Roy (1991). Fishers in the study area were never detected in habitats lacking canopy cover; however, 19% of fisher detections occurred in deciduous forests where overhead cover was low in winter. Possibly, the horizontal cover in stands of aspen and cottonwoods is sufficiently complex to provide fishers with the thermal and escape cover they require for resting, travelling, and foraging. Perhaps fisher use of deciduous forest stands in winter is influenced by the total area of the stand itself and its proximity to mature, contiguous conifer stands. Backtracking of fishers when they are detected in deciduous stands might increase understanding of fisher use of these areas. Are there important food resources or other life history needs that fishers obtain in these stands, or do deciduous stands serve as an impediment to fisher movement and security in winter?

Due to the significant overlap in size and morphology between fisher and marten, snow tracking as a method of detection for theses species is at best 80% effective at accurately identifying individuals in regions where fisher and marten are sympatric (Jim Halfpenny, A Naturalist's World, pers. comm.). Given the conservative criteria for fisher identification, some female fishers were undoubtedly classified as martens. Seasonal or sexual differences among fishers in terms of diet and habitat preferences have not been found in the Rocky Mountains, and few differences have been noted elsewhere (Powell and Zielinski 1994). Although this considerable source of bias makes a comparison between marten and fisher occurrence problematic, it should not confound an analysis of fisher habitat use given the high degree of similarity between the sexes. Under-representation of fishers on the study area probably resulted in an incomplete description of winter distribution and may have contributed to errors associated with smaller sample sizes.

Wolverine

Copeland (1996) found 70.2% of wolverine use in montane coniferous forest types. Wolverine were located in openings on 34% of relocations. A significant preferrence for montane coniferous forests was evident in winter while rock habitats were preferred in summer (Copeland 1996). Hornocker and Hash (1981) found 70% of wolverine use in large areas of medium or scattered mature timber. Wolverine studied by Hornocker and Hash (1981) in NW Montana were reluctant to cross clearcuts or large burns, while wolverine in central Idaho commonly crossed natural openings such as burns, meadows, and mountain tops (Copeland 1996).

Along track transects in GNP, 74.3% of wolverine detections occurred in coniferous and deciduous forests and 25.7% occurred in openings. Wolverines in GNP were often detected in open habitats such as burns, meadows, frozen lakes, and shrubfields. Likewise, wolverine use of these areas was significantly greater than expected given the availability of open habitats along transects. Wolverines were detected in all of the cover types sampled by the transects which was not true of fisher and lynx detections. Wolverines detected in GNP, used deciduous forest cover types significantly more than expected by availability. Use of this cover type was low among wolverine studied by Hornocker and Hash (1981) and Copeland (1996). Both of these studies were conducted west of the Continental Divide where deciduous forests are not widespread. Although deciduous forests retain some overhead cover in winter from branches and tree boles, the overall extent is relatively low (due to leaf loss in fall) compared to conifer stands. GNP receives very little human use in winter and only 10 miles of the park's road system is kept clear snow, rendering the remaining 99.8% of the park *de facto* wilderness. The use of snowmobiles is prohibited inside GNP and very few people make overnight trips into the park's backcountry. This lack of human presence in GNP in winter may be an important factor influencing the movements of wide-ranging carnivores like wolverines. Wolverines detected along track transects in GNP showed no avoidance of open areas and areas of low vegetative cover. Wolverines were observed crossing frozen lakes and foraging along stream courses, on gravel bars, through meadows, and in shrubfields and avalanche chutes. Extensive use of open habitats suggests that these areas may have special significance for foraging, travel, or social interactions. Contrary to observations from other areas, wolverines in GNP were not often detected at lower elevations (where ungulate winter ranges are found) on the west side of the park. The presence of 2 resident wolf packs and high carrion availability would seem to indicate suitable wolverine habitat, but survey results do not support this conclusion. Future research into wolverine food habits in GNP could be extremely informative, as wolverine movements in other study areas appear to be greatly influenced by food availability and distribution. Possibly, carrion is more available on the east side of GNP than on the west side.

When detected in forested habitats in the study area, 81% of wolverine occurrences were in old to intermediate forests (pre 1910) while

19% were in young forests (post 1910). Wolverines used old forests more than young forests along transects, but this pattern was not significant given the stand age classes sampled. Although a preference by wolverine for mature to intermediate forest was evident in northwest Montana (Hornocker and Hash 1981), a similar preference was not noted from studies in Canada (Banci 1994). Copeland (1996) did not investigate wolverine use of stand age classes. Hornocker and Hash (1981) and Banci (1994) suggest that wolverines exhibit a preference for certain habitat characteristics because of greater abundance of food and avoidance of humans. Wolverines detected in GNP used coniferous forests less than expected and did not select forest stands based on age class. Given the wide-ranging movements of wolverines it might not be appropriate to examine wolverine habitat patterns at the stand level. A course-scale analysis of habitat structure and interspersion may be more applicable.

Most wolverine researchers have agreed that "wolverine habitat is probably best defined in terms of adequate year-round food supplies in large, sparsely inhabited wilderness areas, rather than in terms of particular types of topography or plant associations" (Kelsall 1981). Although an abundance of large mammals and a diverse prey base underlie the distribution of wolverines, denning habitat and travel corridors may also be critical for maintaining population viability (Banci 1994). Conclusions about wolverine habitat use are difficult given scant data and the tendency of wolverines to travel widely and use a variety of habitats. It is quite possible that individuals have been detected in areas that could not support home ranges or reproduction (Banci 1994). According to Copeland (1996), "Montane coniferous forests suitable for winter foraging and summer kit rearing may only be useful if connected with subalpine cirque habitats required for natal denning, security areas, and summer foraging."

Summary and Management Recommendations

The winters of 1998/1999 and 1999/2000 saw above average precipitation in GNP's high country (Lisa McKeon, USGS, pers. comm.) Many surveys were conducted under sub-optimal tracking conditions (before 24 hours had passed after a snowfall) as field technicians were available or already in the backcountry on extended trips. Despite the fact that precipitation and snow conditions made complete surveys impossible on numerous occasions, tracks of target species were often detected under sub-optimal conditions. Surveys that were conducted during or immediately after snowfall/rain were treated as reconnaissance surveys. Surveys that followed the protocol explicitly were considered intensive surveys and only data from these surveys were used to calculate encounter rates. The relatively narrow band of montane and sub-alpine forest in the east side drainages, meant that considerably less effort was required to sample the east side compared to the west side which is characterized by contiguous forest cover over a much larger area. In addition, more effort was required to reach sub-alpine forests on the park's west side due to the lower elevation. The higher frequency of deer, elk, and mountain lion detections on the west side suggests that west side transects sampled lower elevation winter range more frequently than east side routes. Although, 34% greater effort was spent on the west side, the likelihood of encountering lynx tracks on the west side was probably lower given the difficulty in accessing areas of suitable lynx habitat (mid-elevations). The size of the study are (4100 km^2) coupled with a small field staff meant that many of the drainages in the park were not adequately sampled. These considerations should be kept in mind when evaluating areas where target species were not detected.

Two winters of snow tracking surveys for forest carnivores in GNP have yielded a tremendous amount of information, and have greatly contributed to the knowledge base of park managers. Prior to these systematic surveys, knowledge of forest carnivores in GNP was scant and consisted mainly of anecdotal observations, unverified sighting records, and a pilot track survey conducted in the mid-1990s (Yates, unpubl. 1994). Marten ecology had been intensively studied in one 15.5 km^2 study area in the SW corner of the park (Hawley 1955, Jonkel 1959, Burnett 1981). No population ecology studies of lynx, fisher, or wolverine had been conducted in the study area, although mountain lion, gray wolf, and coyote populations in the NW corner of the park had been well studied (Kunkel 1997). The intensive forest carnivore detection surveys of 1998/1999 and 1999/2000 have provided important information on the distribution, relative occurrence, and habitat use of several carnivores and associated prey species. The results of these surveys were used in the implementation of the National Lynx Detection Protocol during the summer of 2000 and in a similar benchmark lynx detection survey in the summer of 1999 (Stitt, unpubl. 1999, Edmonds et al. unpubl. 2000). Data on the occurrence of lynx and other rare carnivores in certain areas of the park has also proven extremely useful to park managers in planning efforts involving the location and operation of commercial services and other infrastructure within the park.

Additional surveys should focus on returning to areas where lynx and other target species were detected to gain more knowledge of their winter distribution in GNP. A radio-telemetry study is needed to validate the results of this survey and provide information on the habitat requirements of these species. The impacts of recreation on lynx, fisher, and wolverine should also be the focus of any future studies. Two, two-person teams on the west side of GNP could better cover areas that have received insufficient scrutiny in the past. Additional snow tracking surveys should also focus on areas such as the North Fork and the Middle Fork where potential lynx habitat has been identified, and historical lynx occurrence has been documented but current information is limited. Efforts should be made to sample these areas more intensively in order to expand our knowledge of lynx and other target species in these areas. Additional remote camera systems could also contribute to the survey effort by providing photographic evidence of target species; however, the expense of this method precludes its wide application. One advantage of remote camera systems is that they can be deployed by technicians lacking the expertise necessary to conduct track surveys.

Most of the higher elevation areas on the west side of the Divide have not been surveyed sufficiently due to high avalanche danger and limited access. These areas should be the focus of alternative survey methods such as hair-snare stations during the snow-free months, because they cannot be safely or efficiently sampled during winter. Baited track plates have proven effective at detecting marten and fisher with 100% accuracy (unlike snow tracking) and can be used to monitor population trends as well (Zielinski and Stauffer 1996). Snow tracking and remote cameras are still the only noninvasive methods known to effectively detect wolverine presence although a hair-snare approach may eventually be possible (J. Copeland, Idaho Fish and Game, pers. comm.). According to the Lynx Science Team (Ruggiero et al. 2000),

> "Because a primary objective of management actions will be to enhance habitat conditions for both lynx and snowshoe hares, monitoring of hare populations with pellet transects (e.g., Krebs et al. 1987) and lynx populations with snow tracking or other techniques (e.g., Thompson et al. 1989), will likely be critical components of monitoring strategies."

Although several researchers have found track counts to be a highly effective index for estimating populations of small mammals including snowshoe hares, great effort must be made to standardize the methodologies and to account for natural variation and observer bias (Thompson et al. 1989, Koehler et al. 1990, Monthey 1986). Because animal activity in winter is influenced by weather (e.g., temperature, precipitation, and wind), snow conditions, presence of predators, and social interactions, track counts may be highly variable. Over winter mortality may result in significantly higher track counts in early winter than late winter especially for harvested species like marten (Thompson et al. 1989). Increasing snow depth and colder temperatures may contribute to lower track counts for subnivean species such as weasels and red squirrels in January-February than in December or March (Halfpenny and Biesiot 1986). Track counts may be most effective for monitoring snowshoe hare populations as their counts do not appear to vary significantly between months (Thompson et al. 1989). These potential sources of variation need to be considered when designing a monitoring protocol using track transects, and efforts should be made to standardize the results to the highest degree practicable.

Although GNP's carnivore detection surveys lacked the rigour of a radio-telemetry based study or the statistical power of a stratified random sampling design, a fairly large data set for lynx, fisher, and wolverine has proven useful for describing the distribution and habitat use patterns of these species in the areas sampled. Given the dearth of information on forest carnivores in the U.S. portion of the Rocky

Mountains, any data that have been systematically collected and verified are of value to managers and researchers. More comprehensive vegetation data for the study area will be available in 3-5 yrs. and should be used to re-evaluate the results of this study. Survey results from 1998-2000 have provided important baseline information on the distribution of lynx, fisher, and wolverine as well as numerous other wildlife species active in winter in GNP. This information has already been valuable for park management and planning, and should prove useful in the future as well, if the park chooses to allow more intensive research involving radio-telemetry. The cost-effectiveness and relative non-invasiveness of snow tracking also make this method ideal (both politically and logistically) for use in wilderness areas where the preservation of wilderness values is paramount. From a management perspective, the development of a proven and economical monitoring program for sensitive species such as lynx, fisher, and wolverine is essential. Where possible, a multi-species approach to ecological monitoring is preferred due to the overwhelming challenges federal land managers face in tracking the status of the numerous threatened, endangered, and sensitive species in their charge. Besides developing a monitoring strategy that will detect ecological change, scientists and managers also need to be able to understand these changes so that effective management actions can be recommended (Krebs 1991).

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APPENDIX A.

TRACK OBSERVATION FORM

Species Observed ______________________ Number Observed _____

Date ____/____/____ Time _______ Observers ____________________

Location ____

S____ T____ R____ UTM's _ _ _ _ _, _ _ _ _ _ _

Elev. __________ Aspect __________ Photos Taken? Yes _____ No _____

Habitat ____

Hunting District ______________ Road Number ______________

Notes ____

____

Measurements units are cm or in (mark out the units NOT used)
M1, M2, M3 refer to sequential measurements on one trail, i.e. 3 strides or 3 right front prints

Gait	M1	M2	M3	Mean	STD
Stride					
Group					
Straddle					
Center Straddle					
Trough					

Photograph Record		
Film and ASA	Roll Number	Frames

	Length					Width				
Prints	M1	M2	M3	Mean	STD	M1	M2	M3	Mean	STD
Front										
Hind										
Metatarsal										

Comments and Drawings (make drawings on the back of this form)

APPENDIX A.

SNOW TRACKING AND HABITAT FORM

Observers ______________________________ Sheet ____ of _____
Date ____/____/____ Hunt. Dist. No. ______ Days since last snow _____
Survey Area ______________________________
General Comments ______________________________

Time	Distance from Start	Canids	Felids	Mustelids	Prey Species	Habitat	STQ	Notes

*Describe the Snow Tracking Quality (STQ) using the chart on the back of this page.

APPENDIX B.

GLACIER NATIONAL PARK
WINTER TRACK SURVEY PROTOCOL

Introduction: The purpose of winter track surveys in GNP is to determine the presence and distribution of wildlife species in winter. A special focus will be on rare species including lynx, fisher, wolverine and wolf, but all species will be recorded in order to collect the maximum amount of data with little additional effort. Habitat characteristics along survey routes will also be documented to better understand winter habitat use by target species.

Route Selection: Survey routes will follow existing trails and closed roads for repeatability purposes. Efforts will be made to survey each route at least three times each winter or until target species are detected. Survey routes should include not only drainage bottoms, but upland areas, ridges and saddles. Surveys will be conducted on skis, snowshoes or foot. Ideal tracking conditions occur 24-72 hours after a fresh snowfall, and surveys should be conducted at this time.

Equipment: In addition to personal survival gear and skis or snowshoes, the following equipment is needed to conduct the surveys: track identification guide (*A Field Guide to Mammal Tracking in North America* by James Halfpenny), 35 mm camera and film (for photo-documentation), tape measure (for measuring tracks and tree DBH), field notebook, pencil, USGS 7.5 minute topographic maps, and data recording forms.

Forms: All track data recorded in field notebooks will later be transcribed onto standard snow tracking forms developed by Zielinski and Kucera (1995). Each survey route will be documented by a separate "Snow Tracking and Habitat Form." Observations of wolverine, fisher and lynx tracks will also be recorded on the "Track Observation Form." Wolf tracks will be noted on GNP's "Wolf Observation Form." All notable track observations will also be recorded on GNP's "Wildlife Observation Report Form" (WORF).

Conducting Surveys: All of the information requested on the "Snow Tracking and Habitat Form" will be recorded in the appropriate spaces for each survey. Hunting district number does not apply to GNP. A complete description of the survey route, weather and snow conditions will be included. Start and end times will also be noted, and all distances will be recorded in kilometers.

A) Recording Tracks:

- The exact location (distance from start in kilometers) will be recorded for each set of lynx, fisher, wolverine, wolf, mountain lion, grizzly bear, black bear and moose tracks encountered during the survey. After the survey, these observations will be documented on the appropriate track observation forms and UTMs will be given.
- At regular intervals (every mile is suggested), all of the more common species will be recorded. Deer, elk, bighorn sheep and mountain goat tracks will be noted but not tallied at this time. Additionally, smaller prey animals (snowshoe hare, red squirrel, grouse, vole, mouse and shrew), marten and the smaller weasels (long-tail, short-tail and least) will be tallied and recorded. A mental count of these species will be kept and recorded periodically. A minimum distance of 10 meters will be observed between counting the tracks of a particular species.
- Tracks of wolf, fisher, lynx and wolverine will be measured and photographed to verify the identification. Multiple measurements will be taken and averaged according to Halfpenny to assure a positive identification. See reverse side for measurement taking instructions.

B) Describing Habitat:

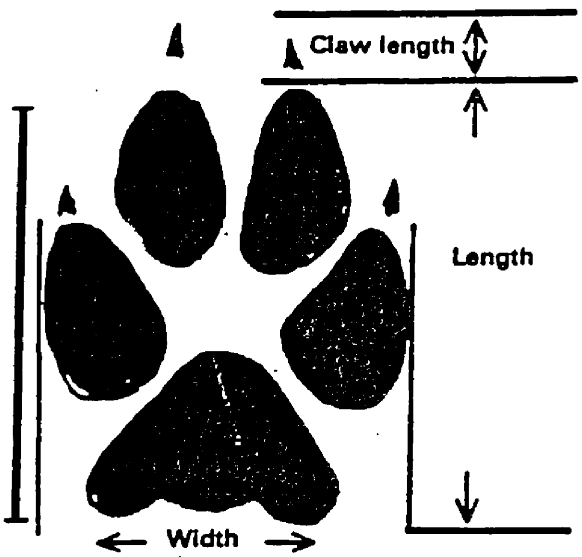
Each time tracks of a target species are encountered or a tally of more common species is made, general habitat characteristics will be described. Dominant tree species will be listed and the vegetative structure class will be noted. Five vegetative structure classes have been described; 1) grass/ forb, 2) shrub/ seedling- stems up to 1 inch DBH, 3) sapling/ pole- DBH between 1 to 7 inches and tree heights ranging 6-45 ft, 4) mature- 10-20+ inches DBH, and 5) old-growth- 20+ inches DBH, abundant snags and down, dead material. Under-story will be described in terms of species composition and density (open, moderate or dense).

C) Snow Tracking Quality (STQ):

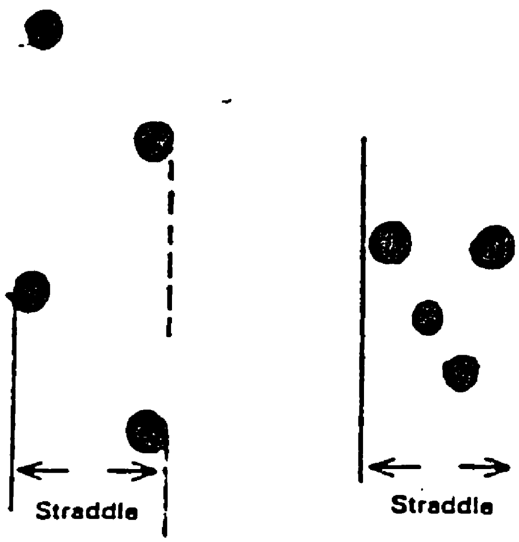
Throughout the survey, the STQ will be will be described using the rating system developed by Zielinski and Kucera (1995) found on the back of the "Snow Tracking and Habitat Form."

Photographs: Higher speed films such as ASA 100 or 200 perform best under variable lighting conditions. Be sure to include an object such as a pen or ruler in the picture for scale. Place it as close to the track as possible to avoid paralax. When not using a flash, shoot straight down on the print. A tripod will help to avoid camera movement. Photograph both individual tracks and trails to document the animal's gait pattern.

Taking Measurements: For more information see James Halfpenny's *A Field Guide to Mammal Tracking in North America.*



The method of measunng print sizes and claw length is shown on the coyote print. Scale is 2 inches (5 cm).



The method of measunng staddle is shown on a coyote (left) and rabbit trail.

The method of measuring stride shown on a bob-cat trail.

APPENDIX C. Number of prey tracks detected per kilometer by survey route; the west side of Glacier National Park, winter 1998-9. The average was calculated for routes that were surveyed more than once, and the range of values appears in parenthesis. N/A applies to routes where snow conditions or travel methods did not permit a tally of prey tracks.

Survey route name	Hare tracks/ kilometer	Squirrel tracks/ kilometer	Grouse tracks/ kilometer	Microtine rodent tracks/ kilometer
Apgar Lookout	4.8	8.9	1.9	1.8
Mt. Brown	1.6	7.3	0.0	3.6
Autumn Creek	1.0 (0.6 - 1.4)	1.0 (0.4 - 1.6)	0.1 (0.0 - 0.2)	0.0
Avalanche Lake	1.7	1.7	0.2	0.5
McGee Meadow Loop	1.6 (0.1 - 2.7)	4.0 (0.4 - 10.2)	0.4 (0.0 - 0.9)	1.6 (0.04 - 7.0)
Howe Ridge	3.7 (3.1 - 4.3)	2.2 (0.6 - 3.3)	0.4 (0.3 - 0.5)	1.0 (0.3 - 2.4)
Huckleberry Mountain	1.8	6.9	0.6	0.7
Snyder Lake	0.8 (0.5 - 1.4)	1.2 (0.0 - 2.7)	0.2 (0.1 - 0.2)	0.2 (0.0 - 0.6)
Lincoln Lake	0.3 (0.0 - 1.2)	1.3 (0.2 - 2.6)	0.2 (0.0 - 0.3)	0.9 (0.3 - 1.6)
McDonald Crk, W Side	2.0 (1.8 - 2.1)	3.0 (2.9 - 3.2)	0.0	1.0 (0.0 - 2.0)
Ole Creek	3.4 (0.7 - 6.1)	1.5 (0.5 - 2.0)	0.2 (0.0 - 0.3)	0.4 (0.0 - 1.0)
Bowman Creek	2.1	0.7	0.2	0.1
West Glacier Bike Path	N/A	N/A	N/A	N/A
Camas Road, W End	N/A	N/A	N/A	N/A
Flathead Ranger Sta	1.3	0.4	0.5	0.1
Soldier Pass	3.5	4.8	0.0	0.6
Harrison Lake	0.8	1.0	0.1	0.1
Lake McDonald Trail	1.8	1.3	0.1	0.5
Logan Creek	1.2 (0.0 - 2.3)	0.5 (0.3 - 0.7)	0.1 (0.0 - 0.3)	0.1 (0.0 - 0.3)
Mineral Creek	1.0	0.3	0.0	0.3
Polebridge - Logging RS	2.1 (1.2 - 3.1)	2.3 (0.8 - 3.7)	0.4 (0.0 - 0.8)	0.3 (0.2 - 0.4)
Logging RS - Camas	1.1	6.9	1.0	0.0
Kishenehn RS Trail	2.2 (0.6 - 3.8)	2.1 (1.9 - 2.4)	0.1 (0.0 - 0.1)	0.2 (0.0 - 0.3)
Kishenehn RS- Kintla Lk	0.5	1.1	0.1	0.2
Kintla Lk, N shore	0.9	0.3	0.0	0.0
Quartz Ridge Trail	2.9	0.9	0.6	0.5
Cerulean Ridge Trail	0.3	0.2	0.0	0.1
Camas Creek	1.4	0.9	0.5	0.1
Average Density:	1.75	2.40	0.30	0.57

APPENDIX D. Number of prey tracks detected per kilometer by survey route; the east side of Glacier National Park, winter 1998-9. The average was calculated for routes that were surveyed more than once, and the range of values appears in parenthesis. N/A applies to routes where snow conditions or travel methods did not permit a tally of prey tracks.

Survey route name	**Hare tracks/ kilometer**	**Squirrel tracks/ kilometer**	**Grouse tracks/ kilometer**	**Microtine rodent tracks/ kilometer**
Summit/Midvale Crks	6.8 (2.6 - 11.9)	0.6 (0.3 - 1.4)	0.3 (0.1 - 0.4)	0.1 (0.0 - 0.1)
Two Medicine Creek	0.5 (0.1 - 0.9)	0.05 (0.0 - 0.2)	0.1 (0.0 - 0.1)	0.0
Two Medicine Lake	10.2	2.8	0.3	0.0
Dry Fork Creek	3.1	0.4	0.2	0.1
Cut Bank Creek (lower)	2.1 (0.0 - 5.7)	0.3 (0.0 - 0.9)	0.1 (0.0 - 0.4)	0.04 (0.0 - 0.1)
Cut Bank Creek (upper)	5.0	0.2	0.0	0.0
Cut Bank Ridge	4.5	1.0	0.5	0.0
Divide Mtn BIR Loop	1.6 (1.5 - 1.8)	1.3 (0.7 - 1.7)	0.3 (0.0 - 0.6)	0.0
Curly Bear Ridge	1.5 (1.3 - 1.8)	1.1 (1.1 - 1.1)	0.4 (0.3 - 0.5)	0.0
1913 Ranger Sta Loop	0.4 (0.3 - 0.6)	0.4 (0.2 - 0.6)	0.5 (0.0 - 0.9)	0.1 (0.0 - 0.3)
Red Eagle Creek	0.1	0.3	0.1	0.2
Napi Point swath	0.7	0.8	0.0	0.0
Two Dog Flats	2.4	12.8	1.6	0.0
Rose Creek	1.2 (0.3 - 2.1)	1.0 (0.7 - 1.2)	0.1 (0.0 - 0.2)	0.1 (0.0 - 0.2)
St Mary Lake, N shore	0.9 (0.3 - 1.6)	0.7 (0.7 - 0.7)	0.1 (0.0 - 0.3)	0.1 (0.0 - 0.1)
Baring Creek	3.0	1.0	0.0	0.5
St Mary River (upper)	1.2 (0.8 - 1.7)	0.6 (0.3 - 0.8)	0.1 (0.0 - 0.1)	0.0
Preston Park	4.6	0.0	0.0	0.0
Boulder Ridge swath	1.5	3.1	2.3	0.0
Many Glacier Road	0.2 (0.1 - 0.2)	0.04 (0.0 - 0.1)	0.0	0.04 (0.0 - 0.1)
Cataract Creek	1.0	0.8	0.3	0.0
Swiftcurrent Creek	1.0 (0.9 - 1.0)	0.3 (0.2 - 0.4)	0.1 (0.0 - 0.1)	0.0
Wilbur Creek	1.5	0.0	0.0	0.0
Swiftcurrent Ridge	0.6 (0.5 - 0.7)	0.4 (0.1 - 0.6)	0.1 (0.1 - 0.2)	0.0
Slide Lake	2.1 (0.5 - 3.7)	0.9 (0.3 - 1.4)	0.3 (0.1 - 0.6)	0.1 (0.0 - 0.1)
Hwy17 (Chief Mtn Rd)	0.6 (0.4 - 0.8)	0.5 (0.0 - 1.0)	0.0	0.0
Lee Ridge Trail	4.3	3.0	0.0	0.5
Belly River Ranger Sta	0.1	0.2	0.0	0.0
Mokowanis Lake	0.1	0.03	0.0	0.0
Average Density:	2.16	1.20	0.27	0.06

APPENDIX E. Number of prey tracks detected per kilometer by survey route; the west side of Glacier National Park, winter 1999-2000. The average was calculated for routes that were surveyed more than once, and the range of values appears in parenthesis

Survey route name	Hare tracks/ kilometer	Squirrel tracks/ kilometer	Grouse tracks/ kilometer	Microtine rodent tracks/ kilometer
Kishenehn RS – Kintla Lk	0.4	0.8	0.03	0.02
Ford Cabin – Ft Kintla Lk	0.4 (0.1 – 0.9)	1.4 (0.2 – 2.2)	0.2 (0.1 – 0.3)	0.01 (0.0 – 0.03)
Bowman Creek	1.5 (0.3 – 2.7)	0.2 (0.0 – 0.3)	0.2 (0.2 – 0.2)	0.0
Polebridge – Ford Cabin	0.3	0.1	0.2	0.0
Polebridge – Winona Lk	0.5	0.2	0.0	0.0
Numa Lookout	1.9	9.2	1.4	0.5
McGee Loop	1.7 (0.8 – 2.4)	1.2 (0.3 – 2.8)	0.6 (0.3 – 0.9)	0.3 (0.0 – 0.4)
Camas Creek	0.3	0.8	0.4	0.2
Howe Ridge	2.1	1.3	0.2	0.0
Snyder Lake	2.6	1.1	0.5	0.0
Lincoln Creek	0.3	0.8	0.0	0.0
Logan Creek	1.5 (0.0 – 5.2)	0.3 (0.0 – 0.8)	0.02 (0.0- 0.1)	0.06 (0.0 – 0.3)
Logan Cr – Granite Park	1.3 (1.1 – 1.6)	0.4 (0.4 – 0.5)	0.3 (0.2 – 0.5)	0.0
Lower Nyack Creek	0.1	0.6	1.1	0.0
Upper Nyack Creek	0.5	1.4	0.3	0.07
Lower Coal Creek	1.2	1.7	0.8	0.2
Upper Coal Creek	0.1	0.4	0.1	0.0
Harrison Creek	0.6 (0.1 – 1.2)	0.5 (0.3 – 0.7)	0.4 (0.1 – 0.7)	0.0
Loneman Lookout	0.1	0.05	0.0	0.03
Lower Park Creek	4.0 (0.3 – 7.5)	0.05 (0.0 – 0.1)	0.2 (0.01- 0.4)	0.0
Upper Park Creek	0.4	0.2	0.1	0.0
Soldier Pass	1.3	0.2	0.1	0.0
Ole Creek	0.4 (0.03- 1.0)	0.1 (0.0 – 0.4)	0.0	0.0
Lake Isabel	1.1	0.3	0.03	0.0
Average Density:	1.0	0.97	0.29	0.05

APPENDIX F. Number of prey tracks detected per kilometer by survey route; the east side of Glacier National Park, winter 1999-2000. The average was calculated for routes that were surveyed more than once, and the range of values appears in parenthesis. N/A applies to routes where snow conditions or travel methods did not permit a tally of prey tracks.

Survey route name	Hare tracks/ kilometer	Squirrel tracks/ kilometer	Grouse tracks/ kilometer	Microtine rodent tracks/ kilometer
Swiftcurrent to Cracker Flats	7.3 (2.2-12.3)	0.7 (0.3-1.0)	0.2 (0.0-0.3)	0.3 (0.0-0.6)
Ptarmigan Lake	10.7 (2.6-18.7)	0.4 (0.0-0.7)	0.3 (0.1-0.4)	0.7 (0.5-0.9)
Swiftcurrent Lake, S shore	4.4 (2.8-6.0)	3.0 (2.0-4.0)	0.3 (0.3-0.2)	0.3 (0.0-0.5)
Belly River RS	0.4	2.7	0.4	5.1
MG Hotel to Morning Eagle Falls	5.0 (1.3-8.7)	1.8 (0.8-2.8)	0.0	0.0
Autum Creek (Marias-Lubec)	9.3 (1.7-23.4)	1.8 (0.3-4.3)	0.3 (0.0-0.8)	0.6 (0.0 – 1.5)
Swiftcurrent Creek	8.7 (0.8-17.7)	0.3 (0.0-0.6)	0.2 (0.0-0.4)	0.3 (0.0 – 0.7)
Josephine Lake, S shore	9.7 (1.2-22.2)	5.1 (1.2-6.5)	0.4 (0.0-0.2)	0.5 (0.0 – 0.7)
Marias Pass to Blacktail hills	1.8	0.3	0.1	0.0
Autum Cr (Lubec to E.Glacier)	5.3 (1.2-9.9)	1.4 (0.3-1.9)	0.2 (0.0-0.4)	0.2 (0.0-0.6)
Pitamakan Pass Trail	14.6	1.2	0.2	0.8
Poia Lake trail	5.7	0.8	0.3	0.4
Divide Boundary swath	1.9	2.8	1.3	0.1
Preston Park	0.3	0.0	0.0	0.0
GTSR to foot of ST Mary Lake	2.3	0.7	0.0	0.0
89 to Cutbank RS	N/A	N/A	N/A	N/A
Upper Cutbank Creek	0.6	0.1	0.1	0.1
Average Density:	5.2	1.4	0.3	0.6